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Original Communications

PULMONARY RESECTION IN THE TREATMENT OF TUBERCULOSIS

INTRODUCTORY REMARKS

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THESE introductory remarks are not to include my own personal case reports of pulmonary resection. In the papers to follow such work will be presented. Rather, I wish to enumerate and to emphasize the difficulties with which you and I have had to contend during these developmental years, these years of hesitation and of disappointments, as we have wound along the uphill tortuous path toward acknowledged success in the arrest—perhaps occasionally eradication—of essentially unilateral, even unilobar, pulmonary tuberculosis.

In the amazing strides forward, scarcely without interruption in the field of thoracic surgery, new procedures in this domain have followed uniformly a regular pattern.

First the announcement of the procedure itself and its recommendation for a particular condition usually presenting a small, often very small, series of cases recently done and with conclusions manifestly too inadequate to be at all convincing. There follows scepticism by those who hear or read, with very limited, half-hearted, unenthusiastic trial. Their cases are poorly selected for they have no dependable concepts of indication. Their results are discouraging. So at a subsequent meeting or in the literature, disasters are reported and the operation is condemned. After a variable number of months, even years, more mature consideration of their previous disasters, and elimination of certain types and distributions and areas of involvement, sev-

Read at the Twenty-Fifth Annual Meeting of the American Association for Thoracic Surgery, Chicago, Ill., May 5 and 6, 1944.

eral men, often with little previous warning to their conferees, report excellent results. A wave of almost violent enthusiasm is very likely to follow. The operation may at once take preference over less radical and quite dependable procedures—much safer immediately and remotely. Finally, sane, sound leisurely comparison is made of the older well-established surgical methods and the new one. Proper evaluation is made. The new procedure is slipped into the niche in which it rightfully belongs and we are ready, whether we realize it or not, to take on another new procedure and to follow a similar cycle.

The operations of lobectomy and pneumonectomy in pulmonary tuberculosis are running true to form. We are deep in the enthusiastic phase. That this is so is a matter of much gratification to me. It ensures beyond peradventure the permanence of these two surgical methods. It does not by any means, however, signify that we are yet competent to choose the correct cases for these procedures or to manage with a minimum of risk the preoperative, operative, and postoperative courses. I am convinced that the papers to follow will go a long, long way in excluding the cases we must not touch, those that would do fully as well or better following another less radical operation, and those where the single or multiple removal of lung lobes is shown to be, from the experience of those men who talk today, clearly the procedure of choice.

What then are the criteria that render pulmonary resection definitely the procedure of choice? In case of doubt are we justified in advising lobectomy or pneumonectomy, or should we first try thoracoplasty?

Thoracic surgeons competent both in offense and defense will discuss those fundamental problems.

The most serious complications that have given us pause in the past have been and are: The two fearsome factors of (1) contralateral extension of the disease to other lobe or lobes and (2) postoperative suppurative pleuritis without, though usually with, secondary pyogenic infection. Then the less serious but still important (3) bronchial fistula with persistent sinus and (4) positive sputum from stump with, or without, bronchial fistula.

From the speakers and discussants in this symposium, we are about to learn of the progress they have made in combating these complications. For upon the degree of success they have attained, the security of these operations depends.

With these preliminary and purposely general remarks concerning the difficulties that have faced us all in establishing the value of lobe or lung removal for pulmonary tuberculosis and in reducing the postoperative hazards, immediate and remote, the presentation of papers on this subject is now in order.

(*See discussion on page* 45.)

TOTAL AND PARTIAL PNEUMONECTOMY IN THE TREATMENT OF PULMONARY TUBERCULOSIS

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AT THE meeting of the American Association for Thoracic Surgery in Cleveland, 1940, Dolley and Jones reported their experience with lobectomy and pneumonectomy for tuberculosis. Their results as well as those of others who joined in the discussion were discouraging. It is noteworthy that at the same meeting Blades presented a paper, in the preparation of which Kent had collaborated, upon the individual ligation technique for lower lobe lobectomy. In 1942, Thornton and Adams collected twenty-nine cases of pneumonectomy and forty-six of lobectomy from the literature to which they added five cases of their own. It is reasonable to assume that the majority of these eighty cases were done by the tourniquet technique although presumably their own were by dissection. The mortality of the pneumonectomies in this group was 44.83 per cent and there were only 41.38 per cent satisfactory results. The mortality of the lobectomies was 25.49 per cent and 68.62 per cent gave satisfactory results. The excision of tuberculous lobes or lungs by the tourniquet technique was bound to give unhappy results in many cases because of tuberculous tissue being cut through in the process of amputation. This in itself resulted in a continuing tuberculous process and when the stump of the bronchus opened as was almost inevitable, the patient had, in addition, a secondarily infected tuberculous empyema. It is apparent that attempts to assess the value of these procedures should be based upon those done by the dissection technique, those done with a tourniquet being regarded as of interest only as a stage in the development of thoracic surgery.

Our first experience with lobectomy for tuberculosis was in November, 1936, when a tourniquet lobectomy was done by Dr. N. S. Shenstone upon a patient who had a persistent cavity of two years' duration in a lower lobe. The operation was followed by a secondarily infected tuberculous empyema and a bronchial fistula. The convalescence was stormy and a local thoracoplasty was required subsequently to obliterate the empyema and close the fistula. The final result was excellent and the patient has remained well. Despite this the procedure was regarded as unsatisfactory.

It was after we had become familiar with the use of the dissection technique in lobectomy for nontuberculous bronchiectasis that we again

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Based on the experience of Dr. N. S. Shenstone and the author.

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became interested in its application to tuberculous lesions. Since October, 1940, seventeen partial pneumonectomies and fifteen total pneumonectomies have been performed. The most frequent indication for the former has been an open cavity with positive sputum. In some cases the cavity had remained open in spite of an apparently adequate collapse by pneumothorax; in others pneumothorax was impossible because of pleural adhesions. Several completely collapsed lower lobes continued to be the source of positive sputum despite the fact that no cavity could be demonstrated by ordinary x-rays or laminagraphs. One middle lobe was excised because of a stenosis of its bronchus. In only one case was the removal of an upper lobe undertaken deliberately when thoracoplasty would have been ordinarily the procedure of choice. Our experience is as yet insufficient to permit expression of an opinion as to whether or not such a decision is justifiable. The chief obstacle would seem to be that what would appear from a radiologic standpoint a perfectly simple procedure may prove exceedingly difficult because of extensive adhesions, chiefly between the diseased and adjacent lobes and/or incomplete development of the interlobar fissures. Lobectomies for cavities in close proximity to the interlobar fissures are likely to be difficult or even impossible. Neither partial nor total pneumonectomy should be undertaken while the bronchoscopic appearance still suggests the presence of an active tuberculous bronchitis at or near the site at which the bronchus will have to be divided. The commonest indication for total pneumonectomy has been stenosis of the bronchus. Patients operated upon for other reasons will be described in detail later.

Little need be said about the technique employed. The posterolateral approach has been used in all cases without removal of a rib. In dividing the pleura about the hilum care has been exercised to cut well away from the mediastinum in order that the rent may be closed subsequently without undue tension. When, because of incomplete development of the primary fissures or the presence of inflammatory adhesions which could not be separated by dissection, it became necessary to divide through lung tissue, the division has been made through the adjacent healthy lobe. The smallest amount of the normal lobe consistent with safety has been sacrificed and in suturing the cut surface care has been taken to avoid undue puckering and thus interference with expansion. The bronchus, whether lobar or main, has been severed as far proximally as possible so that it may be covered with ease. The cut end of the bronchus has been closed in the simplest possible manner, with a running suture of chromic catgut on an atraumatic needle; sometimes with such a suture reinforced by a few interrupted stitches of fine silk. We are in doubt as to whether there is any virtue in the addition of the silk sutures. Two or three stainless steel wires have been used to approximate the ribs following all thoracotomies for the past five years. This not only produces a more secure closure of the wound but because the ribs are held so firmly greatly lessens postoperative pain. I should

like to take this opportunity to emphasize that the periosteum is elevated from the rib margin before each suture is passed so that the wire lies directly against the rib and does not press upon the intercostal structures.

Six patients had a persistent cavity in the upper lobe with positive sputum, in spite of an apparently adequate selective collapse of the lobe. Four of these have had very satisfactory results and are working. One had a pneumothorax on the opposite side for control of a minimal lesion before operation and is still under treatment but sputum-free and making very satisfactory progress. One made a good recovery from operation but a slight narrowing of the main bronchus, known to have been present before operation but apparently not associated with ac-

TABLE I

UPPER AND MIDDLE LOBE LOBECTOMIES

NO.	DATE	AGE	SURGICAL INDICATIONS	COMPLICATIONS	PRESENT CONDITION
			Upper Lobe Lobectomy		
1	4/18/42 H. M.	27	Persistent cavity in spite of selective pneumothorax	Delayed expansion of lower lobe, now complete	Working since August, 1943; well
2	3/25/42 A. O.	28	Persistent cavity in spite of selective pneumothorax	Collapse of opposite lower lobe, cleared by bronchoscopy; increasing stenosis of lower bronchus	Died December, 1943, following lower lobe lobectomy for bronchiectasis that resulted from stenosis
3	5/ 5/42 M. B.	29	Persistent cavity in spite of selective pneumothorax	Staphylococcus infection of wound	Well; doing her own housework
4	4/21/43 J. M.	13	Persistent cavity in spite of selective pneumothorax	Nil	Clinically well; 3 months P.O. x-ray showed suspicious shadow in opposite lung; being kept in bed because of this
5	10/27/43 S. A.	31	Persistent cavity in spite of selective pneumothorax	Local tuberculous empyema	Had pneumothorax on opposite side before operation; this is being continued; clinically well, sputum-free
6	12/ 1/43 F. H.	26	Persistent cavity in spite of selective pneumothorax	Nil	Well; sputum-free since operation
7	3/ 8/44 M. N.	19	Fibrocaseous lesion with cavity at apex	Nil	Doing well
			Middle Lobe Lobectomy		
1	7/ 9/43 K. M.	27	Stenosis of middle lobe bronchus	Nil	Clinically well. Sputum positive due to ulceration of stump of middle lobe bronchus

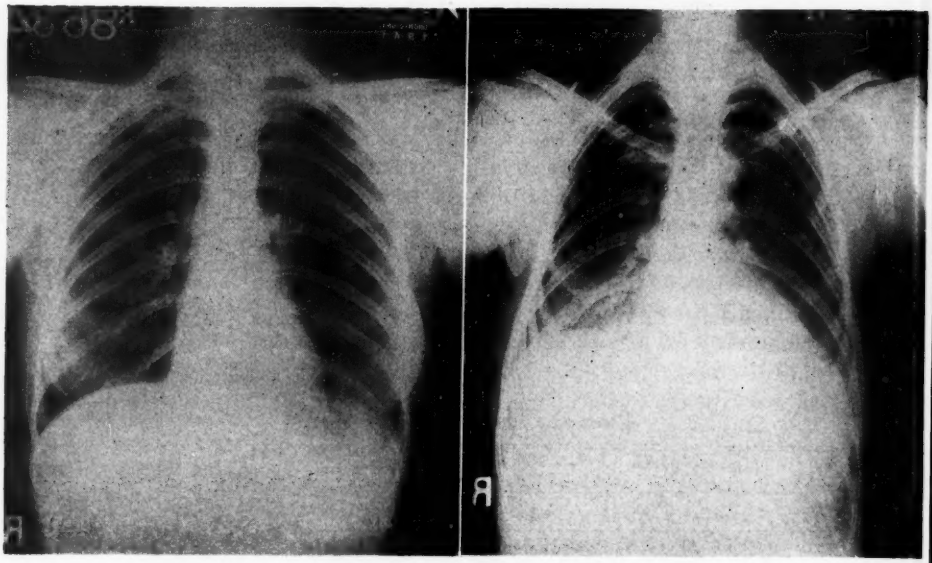


Fig. 1. Fig. 2.

Fig. 1.—Case 3, Table I, November, 1941. Cavity of the right upper lobe.
Fig. 2.—Case 3, Table I, April, 1942. Selective pneumothorax; cavity still open.

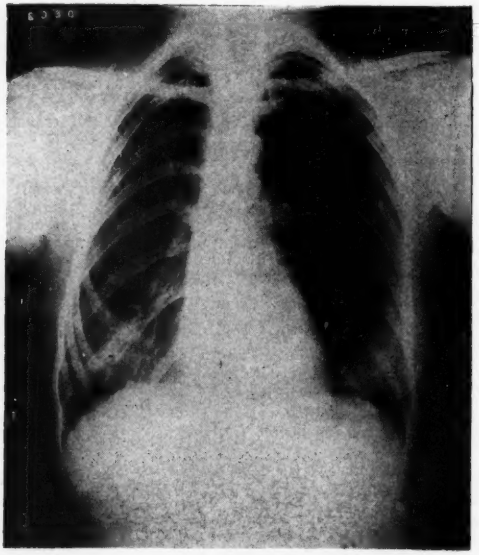


Fig. 3.—Case 3, Table I, December, 1943. Right upper lobectomy, May 5, 1942.

Fig. 4.

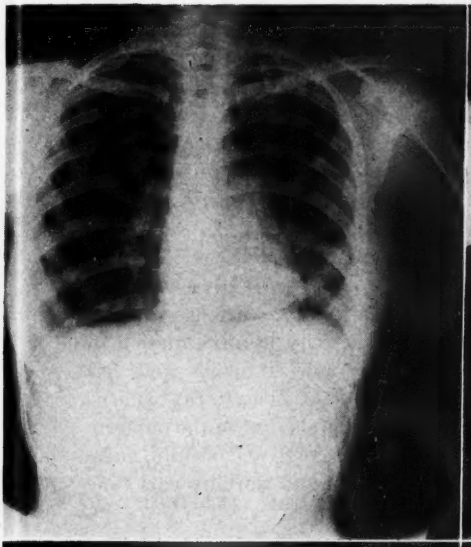
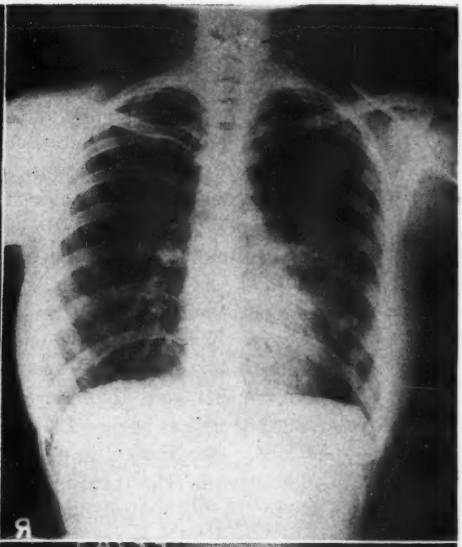


Fig. 5.



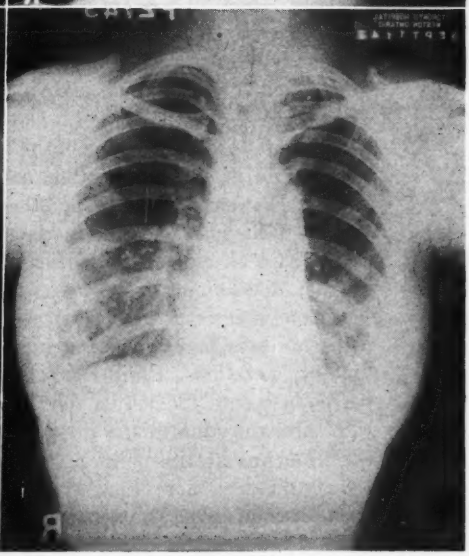


Fig. 6.

Fig. 7.

Fig. 4.—Case 4, Table I, August, 1941. Left upper lobe lesion with cavity.

Fig. 5.—Case 4, Table I, April, 1943. Pneumothorax; sputum remained positive and laminagraph showed cavity in collapsed lobe.

Fig. 6.—Case 4, Table I, September, 1943. Left upper lobectomy, April 21, 1943.

Fig. 7.—Case 4, Table I, December, 1943. Slight activity of right second interspace.

tivity, progressed to an almost complete closure and resulted in a secondarily infected tuberculous bronchiectasis of the lower lobe. This lobe was removed nine months later. Operation was followed by a staphylococcus mediastinitis from which the patient died. If again called upon to deal with a similar situation, the operation of choice would be a pneumonectomy and not a lobectomy. In a seventh patient, a girl 17 years of age, removal of the upper lobe was undertaken deliberately when the surgical indication would ordinarily have been thoracoplasty. She is making a good recovery.

Three lower lobes were removed because they were the source of positive sputum in spite of an apparently complete collapse. All the patients had had pneumothorax but in only one was it present at the time of operation. One had been under treatment in various sanatoriums for ten years. She had some increased activity in an old lesion in the opposite lung following operation but is now clinically well, has negative sputum, and is doing a small amount of housework. One is receiving bed rest at home because of a suspicious shadow in the opposite upper lobe. She is sputum-free and clinically well and should make a good recovery. The third is well, sputum-free, and working part time as a nurse.

Three lower lobes were removed because of persistent cavities and positive sputum. In two, pneumothorax was impossible because of adhesions, and in the third it resulted in ballooning of the cavity. The one patient operated upon eight years ago by the tourniquet method is well. One operated upon in November, 1942, began part-time work as a hospital orderly seven months following operation and has now been working full time for more than one year at a fairly strenuous job. He is in excellent condition. The other patient died forty-three days after operation, having developed a secondarily infected empyema, a bronchial fistula, and an extension of disease upon the opposite side. The fistula did not develop until six weeks after operation. Examination of the specimen suggested the presence of tuberculous bronchiectasis at the point of division of the bronchus. This patient was febrile from the time of operation. Fluid aspirated from the operative area was sterile ten days before the fistula developed so that the empyema and fistula were probably due to the presence of active tuberculosis in the wall of the bronchus at the point of division in spite of the fact that it had shown nothing more than a little reddening when seen through the bronchoscope. The empyema was not recognized at once, however, and early drainage might have resulted in recovery. The patient had been under treatment for only four months at the time of operation and one wonders if a more prolonged period of rest might have rendered the disease less active and made operation safer. Those who have operated upon tuberculous joints know that it is dangerous to undertake excision of a joint without a fairly prolonged period of rest and a similar principle probably applies here.

TABLE II

LOWER LOBE LOBECTOMIES

NO.	DATE	AGE	SURGICAL INDICATIONS	COMPLICATIONS	PRESENT CONDITION
1	11/14/36 A. C.	31	Persistent cavity	Seçondarily infected tuberculous empyema with bronchial fistula (tourniquet technique)	Well; doing all own housework
2	9/18/41 E. H.	49	Positive sputum from collapsed lower lobe	Nil	Well; working part time as nurse
3	12/10/41 A. N.	33	Positive sputum from collapsed lower lobe	Some activity of old lesion other lung	Well; small amount of sputum negative for T. bacillus on culture; doing small amount of housework
4	11/ 2/42 G. Mc.	33	Cavity	Nil	Well; working full time
5	3/11/43 J. J.	18	Bronchiectasis thought nontuberculous	Nil	Well; cough and sputum-free; still in sanatorium
6	7/20/43 G. B.	20	Positive sputum from collapsed lobe	Nil	Well; cough and sputum-free; still in sanatorium
7	8/ 8/43 N. S.	23	Tuberculous lower lobe without cavity; sputum negative	Nil	Well; ready for work
8	11/11/43 G. C.	26	Cavity	Extension of disease on other side; tuberculous empyema, secondarily infected; bronchial fistula	Died on 43rd postoperative day
9	12/12/43 A. O.	28	Secondarily infected tuberculous bronchiectasis beyond stricture of main bronchus; had upper lobectomy 3/25/42	Acute suppurative mediastinitis due to Staph. aureus and Strep. hemolyticus	Died

Two lower lobes were excised for tuberculous bronchiectasis. One operation was undertaken for what was believed to be an ordinary nontuberculous lesion. Repeated examinations of the sputum had shown no tubercle bacilli. X-ray showed a typical triangular shadow. Tubercle bacilli were recovered from a swab taken from the open cut end of the bronchus and bacilli were found in the sputum for one month after operation. Since then the sputum has been negative and the patient is clinically well. The second patient was the one mentioned before who had previously had an upper lobe removed for the cure of an open cavity.

One lobectomy was done to rid a patient of a tuberculous process in the lower lobe because it was thought that his future would be safer in

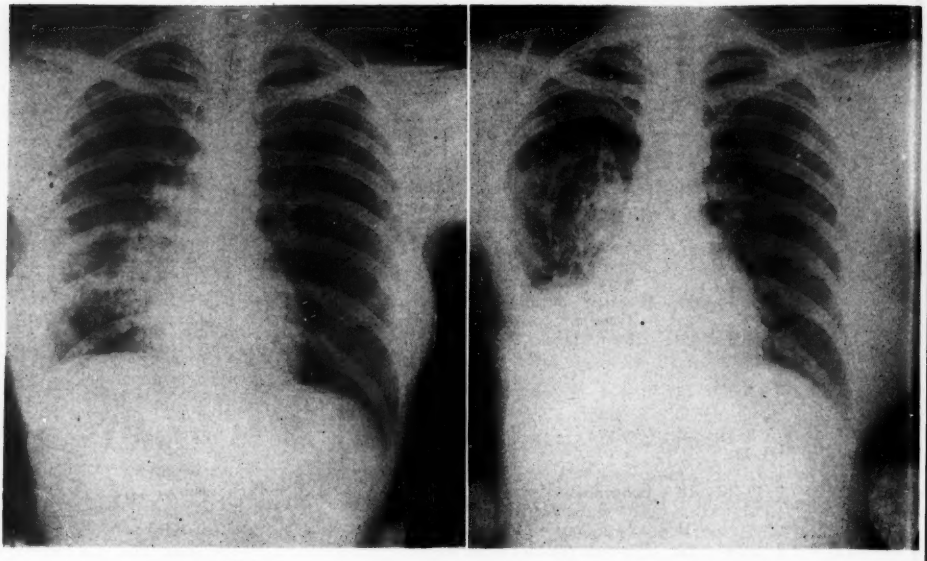


Fig. 8. Fig. 9.

Fig. 8.—Case 1, Table II, May 15, 1936. Cavity of right lower lobe.
Fig. 9.—Case 1, Table II, March 12, 1943. Well; local thoracoplasty was necessary following tourniquet lobectomy, November 14, 1936.

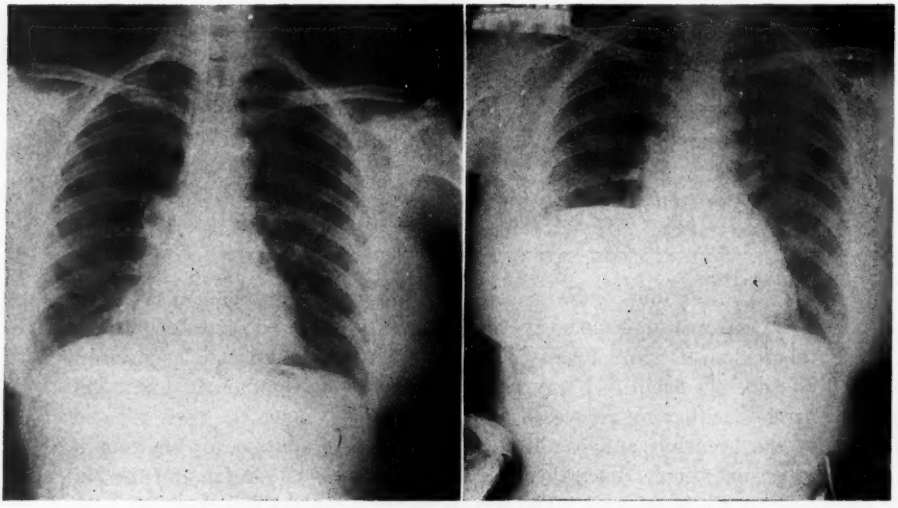


Fig. 10. Fig. 11.

Fig. 10.—Case 2, Table II, Aug. 29, 1939. Right lower lobe collapsed for two years; positive sputum from it.
Fig. 11.—Case 2, Table II, Jan. 9, 1943. Right lower lobe lobectomy, Sept. 18, 1941.

Fig. 12. Fig. 13.

Fig. 12.—Case 4, Table II, October, 1941. Cavity of right lower lobe of two years' history.

Fig. 13.—Case 4, Table II, December, 1941. Cavity ballooned following pneumothorax.

Fig. 14.—Case 4, Table II, March, 1943. Right lower lobe lobectomy, Nov. 2, 1942.

spite of the fact that the sputum had become negative under treatment and no cavity could be demonstrated by x-ray. Progress was very satisfactory and he is now, at the end of six months, ready for work.

The middle lobe lobectomy was done because of a stenosis of the middle lobe bronchus with a collapsed bronchiectatic lobe beyond. Recovery from operation was uneventful and the patient was discharged from the hospital on the fourteenth day. She is, however, still in the sanatorium because of positive sputum which apparently originates from a tuberculous ulceration of the stump of the bronchus. The remainder of the bronchial tree as seen through the bronchoscope looks healthy, and x-ray shows no evidence of pulmonary disease.

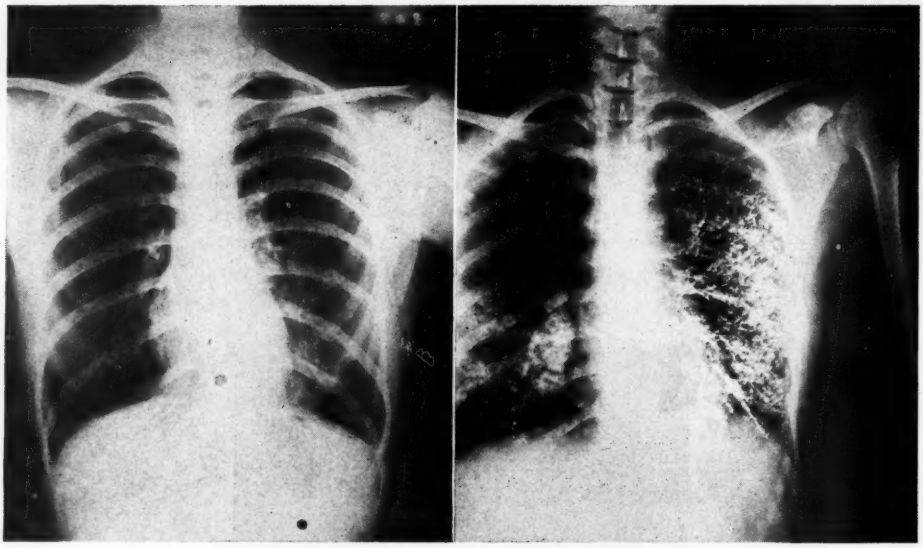


Fig. 15. Fig. 16.

Fig. 15.—Case 5, Table II, Nov. 2, 1942. Plain film of lower lobe lesion.
Fig. 16.—Case 5, Table II, Dec. 7, 1942. Lipiodol showing bronchiectasis for which lobectomy was done Mar. 11, 1943.

Since October, 1940, fifteen pneumonectomies have been done for tuberculosis, ten of which were for stenosis of the main bronchus. Two of the remaining five patients had an extensive caseous and cavernous tuberculosis involving a whole lung; a third had bronchiectasis of the lower and middle lobes. Another patient had a cavity in the middle lobe with extensive tuberculous involvement of the adjacent portion of the upper and lower lobes. The fifth patient had a tuberculoma near the hilum with collapse and bronchiectasis distal to it.

Of the ten patients operated upon for stenosis of the bronchus, seven had an uncomplicated recovery. In three cases the stenosis was at the origin of the main bronchus and tuberculous tissue was divided in sec-

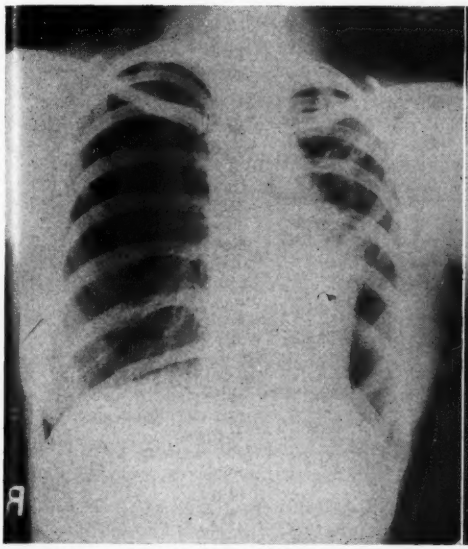


Fig. 17.

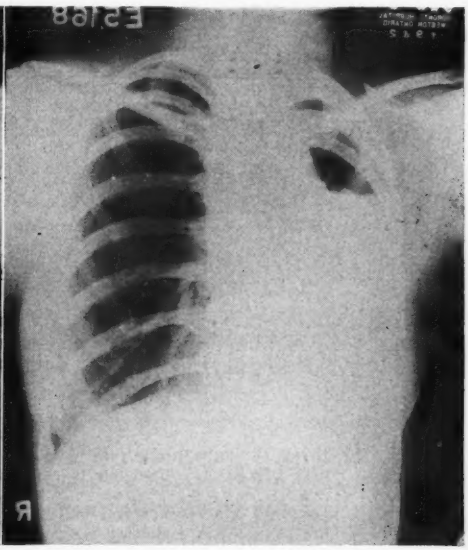


Fig. 18.

Fig. 17.—Case 7, Table III, October, 1941. Stenosis of left main bronchus.
Fig. 18.—Case 7, Table III, January, 1942. Left pneumonectomy, Oct. 15, 1941.

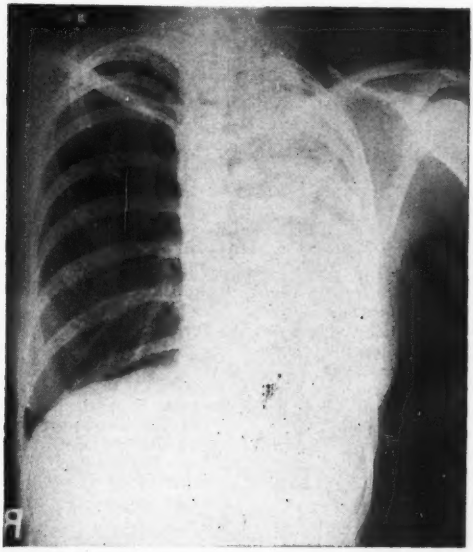


Fig. 19.—Case 7, Table III, September, 1943. Well; working full time.

TABLE III

PNEUMONECTOMIES FOR TUBERCULOSIS TO MAY, 1944

NO.	DATE	AGE	SURGICAL INDICATIONS	COMPLICATIONS	PRESENT CONDITION
1	10/ 3/40 I. W.	36	Stenosis of r. main bronchus	Nil	Well; does own housework
2	12/ 7/40 D. C.	31	Stenosis of l. main bronchus	Nil	Well; working part time as public health nurse
3	5/30/41 B. W.	25	Stenosis of l. main bronchus	Nil	Well; has since married
4	6/24/41 O. T.	47	Stenosis of r. main bronchus	Stormy postoperative course	Fairly well and improving; doing light housework
5	6/27/41 H. S.	22	Stenosis of l. main bronchus	Nil	Well; working
6	7/ 3/41 C. L.	18	Stenosis of l. main bronchus	Nil in postoperative period	Died June, 1943, of extension of preexisting lesion in r. apex
7	10/15/41 D. A.	33	Stenosis of l. main bronchus	Nil	Well; working as telephone operator
8	11/19/41 K. T.	15	Extensive infiltration of whole l. lung with cavitation and hemorrhage	Staph. aureus wound infection; Staph. and T. empyema; bronchial fistula; extensive tuberculosis of other lung	Died 4/27/42
9	2/18/42 M. G.	31	Post-tuberculous bronchiectasis r. lower and middle lobes; upper lobe collapsed by extrapleural pneumothorax	Nil	Fairly well only; Still has moderate amount but much smaller amount of sputum, negative for t.b., from bronchiectasis of l. lower lobe
10	3/ 4/42 M. R.	36	Stenosis of l. main bronchus	Nil	Sputum positive, wheezing respiration; bronchoscopy 11/1/43 showed r. middle bronchus half normal diameter
11	5/15/42 F. L.	23	Stenosis of l. main bronchus and secondarily infected tuberculous bronchiectasis	Postoperative course stormy with high fever	Clinically well but sputum positive due to tuberculous ulceration of stump of bronchus
12	6/ 1/42 A. S. B.	37	Stenosis of l. main bronchus	Secondarily infected tuberculous empyema drained; bronchial fistula; tuberculosis of other lung	Condition poor and apparently hopeless
13	7/28/42 E. A. T.	32	Tuberculoma and bronchiectasis (preoperative diagnosis, cancer)	Nil	Well; working full time

TABLE III—CONT'D

NO.	DATE	AGE	SURGICAL INDICATIONS	COMPLICATIONS	PRESENT CONDITION
14	10/ 7/42 M. I.	59	Tuberculous cavity of middle lobe with infiltration of upper and lower	Dyspnea thought to be asthma	Died on 10th postoperative day of pulmonary embolus (?)
15	12/ 4/43 O. L.	54	Extensive tuberculous infiltration of lung with narrowing of bronchus (preoperative diagnosis, carcinoma)	Streptococcus viridans empyema	General condition quite good; still has empyema

tioning it. One of these is at present clinically well and the other lung is free from disease, but the sputum is positive on culture and bronchoscopy shows ulceration of the divided stump of the bronchus. One patient had a stormy postoperative course but has shown progressive improvement. Her sputum is negative and she is doing light housework. One developed a tuberculous empyema and a bronchial fistula and at present, nearly two years after operation, her condition is stationary. She will probably not get well. Of those whose immediate recovery was uneventful, one has developed a narrowing of the opposite main bronchus to one-half its normal size. This bronchus appeared normal before operation. The sputum has remained positive. The x-ray appearance of the other lung has remained satisfactory. Her condition is undoubtedly hopeless. One died eleven months postoperatively from an extension of a minimal lesion in the opposite apex known to have been present before operation but thought quiescent.

The patient operated upon because of bronchiectasis of the right lower and middle lobes in the absence of stenosis of the bronchus had had right extrapleural pneumonolysis to close an apical cavity two and one-half years previously. Since that time her sputum had been negative for tubercle bacilli but large in amount. She could be kept afebrile only by continuous postural drainage on an inclined plane. It is interesting that the operation was not rendered much more difficult because of the previous pneumonolysis and it is suggested that if collapse of the apex of the lung be considered necessary in a patient who may subsequently require a pneumonectomy this is the procedure of choice rather than thoracoplasty. Convalescence from operation was uneventful and the patient's condition is much improved but she still has some sputum negative for tubercle bacilli, from the left lober lobe bronchus, due presumably to a bronchiectasis of this lobe.

The patient with the middle lobe cavity was thought to have a cavity in the lower lobe. Lobectomy was decided upon in preference to thoracoplasty because it was apparent that an effective collapse would be produced only by a widespread removal of perhaps ten ribs. After the lung had been freed from the chest wall it was found impossible,

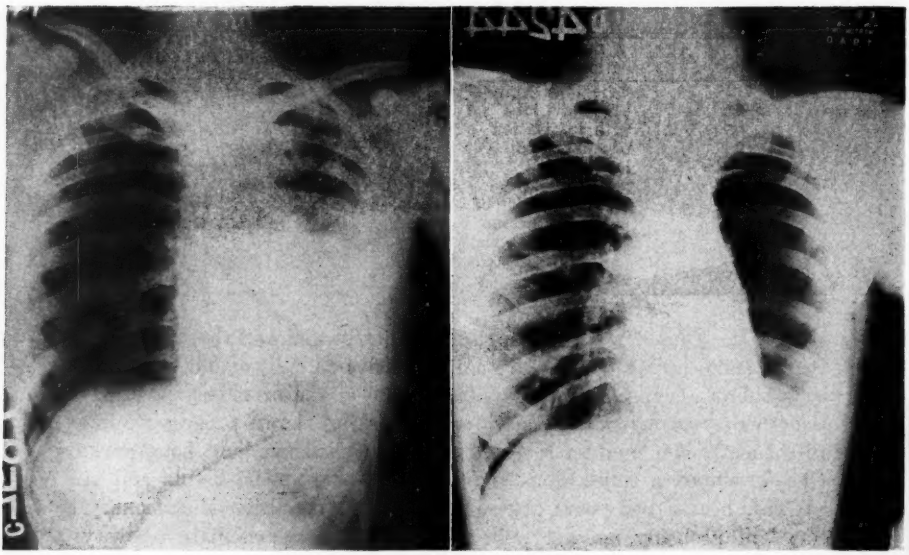


Fig. 20. Fig. 21.

Fig. 20.—Case 10, Table III, August, 1938. Stenosis of left main bronchus.
Fig. 21.—Case 10, Table III, February, 1940. Pneumothorax for two years; sputum still positive in spite of complete collapse.

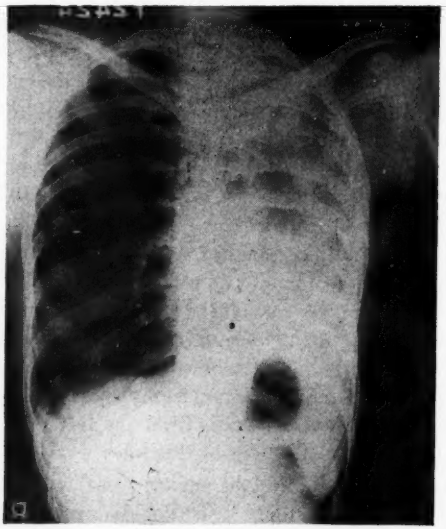


Fig. 22.—Case 10, Table III, August, 1943. Left pneumonectomy, Mar. 2, 1942. This patient has developed stenosis of the right main bronchus.

because of extensive involvement of the adjacent portion of the upper and lower lobes, to separate these from the diseased area and a pneumonectomy became necessary. The patient had difficult breathing of an asthmatic type from the time of the operation but this improved gradually. Before he died suddenly on the tenth postoperative day of what was apparently pulmonary embolism, it was thought that he was going to recover. No autopsy was obtained.

The patient who had the tuberculoma presented a typical x-ray appearance of local bronchial obstruction with a triangular area of collapse beyond it. In spite of negative bronchoscopy the mass shown in the films was thought to be a carcinoma. No calcification could be seen. Convalescence from operation was uneventful and he is now well and working full time. Undoubtedly the proper procedure was carried out under a wrong diagnosis.

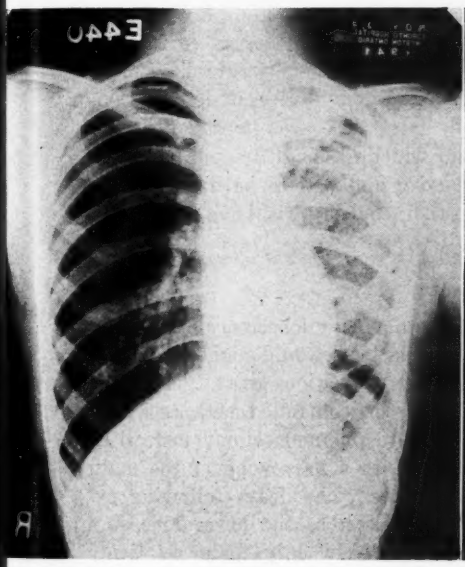


Fig. 23.

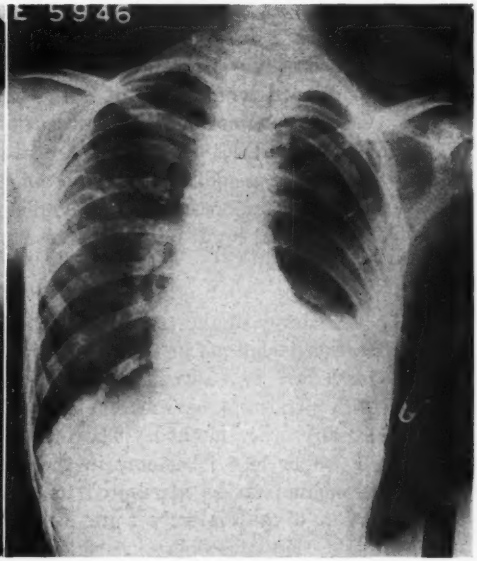


Fig. 24.

Fig. 23.—Case 8, Table III, November, 1941. Infiltration of whole left lung with cavitation and hemorrhage.

Fig. 24.—Case 8, Table III, February, 1942. Pneumonectomy, Feb. 18, 1942; tuberculous and staphylococcus empyema with extensive tuberculosis of opposite lung.

Of the two patients operated upon for an extensive tuberculous process involving one lung, the first, a boy of 15 years, had had tuberculosis for four years. Pneumothorax had been given at one time but the pleural space had been lost. During the week prior to admission he had had four extensive hemoptyses. Because of this and because of the undesirable effects of a complete thoracoplasty at this early age, a pneumonectomy was decided upon. Bronchoscopy showed the bronchi

to be normal. There was no sputum but the gastric contents contained tubercle bacilli on concentration. The operation proved extremely difficult because of the massive infiltration of the lung and because of the presence of many greatly enlarged glands about the hilum. This was the only occasion upon which we have encountered great enlargement of the hilar glands. The pulmonary artery was inadvertently opened and was controlled with some difficulty. The operative time was unduly long. The immediate postoperative condition was fairly satisfactory but a staphylococcus infection of the wound developed and two weeks after operation a staphylococcus empyema, apparently secondary to the infection of the wound. The empyema was drained. A tuberculous process developed in the opposite lung and two months after operation a bronchial fistula formed. The patient died five months after operation of a massive hemorrhage into the empyema cavity. The second patient was thought to have a cancer of the bronchus. An error occurred in that it was thought to have been proved by bronchoscopy. Early in the operation, during the separation of the pleura, an abscess cavity was opened into. Had this not occurred the operation would have been abandoned but because of it the pneumonectomy was completed. Convalescence was unbelievably smooth but there was a streptococcus viridans infection of the pleural fluid which although temporarily controlled by penicillin again became active and had to be drained four months after operation. A complete thoracoplasty will have to be done. Her general condition is satisfactory.

SUMMARY

A survey of the results obtained by pulmonary lobectomy by the dissection technique in this small group of patients would suggest that the procedure is a satisfactory one if proper indications exist. The cases with persistent cavities could not have been controlled with certainty by any other method. The failure to do a pneumonectomy instead of an upper lobe lobectomy in the patient with a narrowing of the main bronchus can be attributed to inexperience. The death following excision of a relatively acute tuberculous lesion of the lower lobe suggests that the operation should be undertaken only upon relatively stabilized lesions. Further experience may show this conclusion to have been incorrect. The fact that the operation may prove technically very difficult, even the one that appears simplest from the x-ray standpoint, must not be lost sight of.

The results of pneumonectomy for stenosis of the bronchus are reasonably satisfactory. It may be that it is unwise to attempt the procedure when the narrowing extends directly to the trachea. These strictures were, however, almost complete and no other treatment could have succeeded. The late involvement of the opposite bronchus in the one case could not have been anticipated or prevented. Such an occasional late complication is perhaps to be expected. The operation upon

the boy with the extensive unilateral disease was probably ill advised but it is doubtful if he would have survived a multiple stage thoracoplasty, the only alternative.

The number of cases upon which the paper is based is too small to be of statistical value or to permit of the expression of dogmatic opinions. Increasing experience, particularly in the selection of cases, should make it possible to avoid in the future at least some of the errors which we have committed. In assessing the results the fact that the cases under consideration are, for the most part, those in which other therapeutic procedures at our disposal have given unsatisfactory results, should not be overlooked. It is in the hope that a knowledge, especially of our failures, may be of value to others that this paper has been presented.

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(*See discussion on page* 45.)

LOBECTOMY FOR PULMONARY TUBERCULOSIS

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THE surgical removal of the involved portion of the lung in pulmonary tuberculosis has usually been considered unwise and extremely hazardous. The reports on lobectomy and pneumonectomy for tuberculosis which appeared in the literature from time to time were not particularly encouraging. An analysis of the reported cases was made by Thornton and Adams[1] in 1942. The most common indications for operation in that collected series were (a) tuberculoma, an isolated tuberculous lesion simulating tumor, (b) tuberculous bronchiectasis, (c) bronchial stenosis, and (d) post-thoracoplastic cavity. In only very few instances was a primary lobectomy performed in preference to a collapse procedure. The most common complications in the series of cases collected by Thornton and Adams were persistent fistula, contralateral spread, and empyema.

In a discussion of lobectomy for pulmonary tuberculosis by Churchill and Klopstock, in 1943,[2] the fallacy of attempting to draw conclusions from this heterogeneous group of cases is emphasized. These authors reported six cases of pulmonary tuberculosis in which lobectomy was performed in the presence of known positive sputum. In three cases the pathologic characteristics of the pulmonary tuberculous process were unfavorable for collapse therapy. In the other three cases orthodox indications for thoracoplasty were present, but a deliberate selection of lobectomy was substituted. All six cases had an uncomplicated postoperative result.

With the marked advance in thoracic surgery which has occurred within the past few years, the hazard of pulmonary resection for suppurative lesions and tumors has been greatly reduced. Improvement in anesthesiology has lessened the hazard of bronchiogenic spread of infection during operation. The application of the hilar dissection technique to lobectomy of upper as well as lower lobes has insured a higher incidence of permanent closure of the bronchus and lessened the incidence of postoperative empyema. It is therefore reasonable to assume that under present circumstances, in properly selected cases, pulmonary resection for tuberculosis might be performed without extreme hazard.

Principles concerned with lobectomy for pulmonary tuberculosis differ in many ways from those involved in total pneumonectomy. Where the tuberculous process is sufficiently localized to make lobectomy

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feasible, removal of the diseased lobe may result in greater conservation of pulmonary function than other surgical procedures. In uncomplicated cases we have not performed any thoracoplastic procedure following lobectomy. Therefore, the mechanics of the thoracic cage are not significantly altered by the operative procedure. By conserving pulmonary function, lobectomy may perhaps broaden the field of therapy in cases of bilateral tuberculosis. Total pneumonectomy, on the other hand, can never be a procedure of choice from the functional standpoint. It is indicated when collapse therapy is considered inadequate or unsatisfactory because of the pathologic characteristics of the lesion in the case under consideration. It should be pointed out, however, that the technical surgical problems encountered in lobectomy in pulmonary tuberculosis are more complicated than those confronting the surgeon in total removal of the lung. In presenting our experience with lobectomy in pulmonary tuberculosis we shall not attempt to draw any final conclusions. The experience and data which we have obtained, however, may be of aid in a later final evaluation of the problem.

The present report on lobectomy in pulmonary tuberculosis is concerned with a detailed analysis of sixteen consecutive patients who have been operated upon during the past one and one-half years. The cases analyzed are limited to instances in which lobectomy was the primary surgical procedure performed for known active pulmonary tuberculosis with positive sputum. Cases in which lobectomy was done after an unsuccessful thoracoplasty are not included. Cases in which lobectomy was performed for bronchiectasis without preoperative knowledge of the existence of tuberculosis in the resected lobe, or in which the tuberculosis was arrested, are also excluded. Finally, no case of pneumonectomy for pulmonary tuberculosis is considered in this presentation. In addition to the sixteen cases in which lobectomy was performed as a primary surgical procedure, eleven patients with tuberculosis have been subjected to lobectomy or pneumonectomy by one of us (H. C. M.) for the various other indications listed. Of the eleven cases of pulmonary resection in the presence of tuberculosis excluded from this report for the reasons mentioned, one patient has died since operation.

SELECTION OF PATIENTS FOR LOBECTOMY

The sixteen cases which comprise this series illustrate a wide variability in the indications for lobectomy. In some instances lobectomy was considered the procedure of choice because the lesion was of a type or in a location which is unfavorable for collapse therapy. In a few cases a good result might have been anticipated from a thoracoplasty. A large number of observations will be required before the advisability of lobectomy in the latter group of cases can be established. The specific indications included the following:

1. Tension cavities which failed to respond to pneumothorax, or where pneumothorax was not obtainable
2. Predominantly bronchial type of tuberculosis, perhaps with little cavitation
3. Lower lobe cavity not responding to pneumothorax
4. Extensive caseation of one lobe with little cavitation, and with disease almost limited to the one lobe
5. A shrunken, destroyed lobe with extensive cavitation with contralateral lung negative or contralateral lung requiring perhaps later collapse therapy
6. Unilobar disease in a young patient in preference to thoracoplasty, especially if still in the growing age period

In a few of the cases lobectomy was undertaken although a cavity or active disease in the other lung was considered a contraindication to thoracoplasty. The conservation of pulmonary function resulting from the lobectomy in comparison to thoracoplasty permitted consideration of later collapse therapy or even lobectomy on the contralateral side. The avoidance of deformity has been a consideration in some of the female patients, but this has never been considered as a sole indication for lobectomy in preference to thoracoplasty. No patients in this series were more than slightly febrile at the time of operation and the majority were afebrile. The general condition in all instances was satisfactory. A few patients, however, showed considerable evidence of tuberculous activity at the time of operation as manifested by an elevated sedimentation rate, slight fever, and an elevated pulse rate. A few of the patients had had extensive bilateral disease one or two years prior to operation, but had cleared most of the involved area, leaving only an extensively damaged lobe on one side. A large amount of sputum was present in only one case and this patient had a fatal contralateral spread from operation.

Tuberculous bronchitis was present in a number of cases, but preoperative bronchoscopy did not reveal ulceration or granulation tissue at the site at which surgical division was required in any case in this series. Stenosis of the lobar bronchus was present in a few cases. If the bronchial lesion involved the main stem bronchus, pneumonectomy rather than lobectomy would have to be considered.

OPERATIVE TECHNIQUE

Many of the complications which occurred following lobectomy for tuberculosis in the cases reported in the literature prior to 1942 may be ascribed to the operative technique employed. The contralateral tuberculous spreads often were caused by unsatisfactory control of the bronchial secretions during operation, or occurred in the postoperative period secondary to bronchial fistula and empyema on the side of operation. The high incidence of bronchial fistula and empyema was

related to the tourniquet type of lobectomy which was usually employed. Whereas good results can be obtained when the tourniquet technique is employed in bronchiectasis, experience has shown conclusively that a hilar dissection technique is an absolute prerequisite for the best results of lung resection in the presence of tubercle bacilli. Because we consider the details of operative and postoperative care to be so important, the matter will be discussed in some detail.

Anesthesia.—All patients in this series were operated upon under intratracheal anesthesia. In most instances an intratracheal tube without a cuff was employed and the closed system was maintained by the use of a Bradshaw mask. Gas-oxygen-ether was employed in all the recent cases. Cyclopropane was used in a few of the earlier cases. Probably one of the main objections to cyclopropane is the rapidity with which the level of anesthesia may change during operation. As intratracheal suction must be carried out at frequent intervals, the plane of anesthesia may become light, which results in marked reflex reaction during intratracheal suction. This occurrence was very evident in one patient in this series who developed a massive tuberculous spread to the contralateral lung, undoubtedly during the operative procedure. We now, therefore, strongly favor the use of oxygen-ether anesthesia for this group of cases. A discussion of the anesthesia is incomplete unless it is stressed that the major burden of the prevention of bronchiogenic spread during operation rests on the anesthetist. Difficulties with the conduct of the anesthesia, including the maintenance of a clear airway, is one of the most important phases of this problem. Intravenous fluids are started at the beginning of the operation and whole blood is given in adequate amounts throughout operation.

Surgical Procedure in Lobectomy.—Throughout the operative procedure great care was taken to obtain good hemostasis and minimize blood loss. Silk technique was used throughout. A posterolateral incision was employed in all cases of lobectomy. In resection of the upper lobe, the fifth rib was resected from the transverse process almost to its costal cartilage, and the sixth rib divided posteriorly to its angle. In lobectomy of the lower lobe, the seventh rib was resected in almost its entire length, and the eighth rib divided close to the transverse process.

If the intrapleural adhesions were vascular, division was carried out between silver clamps or suture ligatures. Whenever the adherence of the pulmonary tissue to the parietal pleura made injury of the tuberculous pulmonary tissue likely, the dissection was transferred to the extrapleural plane. In all areas in which a tuberculous cavity was close to the surface of the lung and adherent to the parietal pleura, the dissection was performed in the extrapleural plane and the parietal pleura left attached to the dissected lung. This is particularly important in adherent cavities near the pulmonary apex posteriorly. The

freeing of the lobe may be a tedious and time-consuming procedure if injury to tuberculous lung tissue and contamination of pleural space is to be avoided. Rupture of the cavity might be a fatal complication.

Inflammatory or tuberculous infiltration of the hilar area is not present in the absence of secondary complications of the pulmonary tuberculosis. The hilar lymph nodes usually show less enlargement and are less of an obstacle to hilar dissection than in most cases of bronchiectasis.

Theoretically, the ideal procedure would be to ligate the main bronchus of the lobe very shortly after the pleural cavity is opened, in order to eliminate the continued drainage of tuberculous secretion into the main air passages. Whereas the main bronchus can usually be isolated as the initial step in total pneumonectomy, the procedure is less readily accomplished in lobectomy, particularly of the left upper lobe. Branches of the pulmonary artery to the left upper lobe may so surround the bronchus as to render initial freeing of the bronchus prior to ligation of these vessels somewhat hazardous. The procedure must be varied depending upon the circumstances, but it may be said that the bronchus should be ligated as early as possible without entailing the risk of hemorrhage from pulmonary vessels. When the lung is densely adherent, considerable freeing of the lung from the chest wall may be necessary before the bronchus can be adequately exposed. Since tuberculous cavities are most commonly located posteriorly, a posterior approach to the bronchus may necessitate previous mobilization of the cavitary portion of the lung.

It is difficult to occlude completely a large-sized bronchus by an encircling ligature. Moreover, this type of ligature is undesirable as a permanent means of bronchial closure. The incorporation of a short piece of stiff rubber tubing within the ligature around the bronchus in such a manner as to have the stiff rubber tube invaginate the membranous portion of the bronchus may permit occlusion of the bronchus without the ligature producing crushing of the tissues. This temporary ligature may later be removed by cutting the silk where it overlies the rubber tube.

All vessels are thoroughly freed and ligated with silk. Transfixion sutures in addition to encircling sutures are employed on all larger branches. If it is necessary to traverse an incomplete interlobar fissure, attempts are made to minimize tissue trauma. Obviously tuberculous lung is not transected, even if this requires abandoning the plan of lobectomy.

The cut end of the bronchus is closed by interrupted silk sutures. The bronchial stump is always covered by a flap of pleura and in addition some of the pulmonary tissue from the remaining lobe may be sutured over the stump. Expansion of the remaining lobe should not be interfered with by the way the pulmonary tissue is brought over

the stump. The phrenic nerve has been crushed in order to produce temporary diaphragmatic elevation following removal of a noncontracted upper lobe. The remaining lobe has been freed of all adhesions to permit full expansion.

We have drained the pleural space by a closed system maintained with a water seal. In patients operated upon for pulmonary tuberculosis, the drain has always been removed within from twenty-four to forty-eight hours following operation. A suture which was previously placed at the site of the drainage tube is tied as the tube is removed in order to prevent air from entering the thorax. In lobectomy of the upper lobe a drainage tube is usually brought out through the lower anterior end of the operative incision, whereas following lobectomy of the lower lobe the drain is usually introduced through a stab wound in the eighth interspace in the posterior axillary line. Drainage for the first day or two after operation facilitates early reexpansion of the remaining pulmonary tissue by the early evacuation of fluid and air from the pleural space. We believe it is undesirable to leave the tube in more than forty-eight hours and it may be best to remove it within twenty-four hours of operation in order to lessen the chance of secondary infection. We have had no difficulty so far as a result of this method of pleural drainage.

Condition During and After Operation.—We have analyzed in detail the operative and postoperative condition in the thirteen consecutive lobectomies performed at Triboro Hospital.* In none of the thirteen cases did the systolic blood pressure drop more than 25 mm. Hg from the beginning to the end of the operation. The average systolic blood pressure at the conclusion of the operation was only 13 mm. Hg lower than at the beginning of the operative procedure. No instance of shock was encountered. The duration of the operative procedure averaged more than four and one-half hours. On return to the ward most patients had a systolic blood pressure over 100 mm. Hg and in only one instance was it below 90 mm. Hg. Blood pressure readings five hours after operation were never lower than 98 mm. Hg systolic pressure. We ascribe this lack of serious disturbance in peripheral circulation to several factors: (1) avoidance of anoxia during operation; (2) relatively small blood loss and minimizing tissue trauma which slow and meticulous operative technique permits; and (3) adequate intravenous therapy, particularly blood transfusions, throughout the procedure. In most instances 1,000 c.c. of blood are given slowly throughout the operation. The amount of blood administered may be considerably more than the amount lost in the operative field. In addition to the blood loss at operation, there is considerable plasma loss into the pleural space and by drainage in the early postoperative period.

*Three of the lobectomies included in this report were performed at other institutions by one of us (H.C.M.).

By this type of prophylactic therapy the patient's blood count usually shows little alteration from the preoperative status.

Oxygen therapy is administered while the patient is transferred from the operating room to the ward, where an oxygen tent is employed. The usual postoperative measures to avoid retention of bronchial secretion are of greatest importance. Bronchoscopy has not been performed routinely after operation.

RESULTS

The results in the sixteen consecutive lobectomies for active tuberculosis are as follows:

Ten patients had an entirely uneventful and uncomplicated postoperative course.

In three patients the postoperative course was uneventful except for radiographic evidence of increased density around areas of pre-existing disease in the contralateral lung. The appearance was not that of a tuberculous spread, and clearing occurred in one case in four days.

One patient developed an apical staphylococcus empyema with small bronchial fistula which required thoracostomy and a later one-stage thoracoplasty. All wounds are now healed.

Another patient developed a tuberculous empyema and evidence of an intermittent, very small bronchial fistula. This patient will require partial thoracoplasty. Considerable pulmonary tissue was divided at the site of an incomplete fissure.

The one fatality among the sixteen cases was due to a tuberculous spread in the contralateral lung which occurred during operation. Death occurred one month postoperatively. This patient had a huge tension cavity with a fluid level; patient was febrile and toxic. Cavernostomy was the only alternative.

The status of sputum studies at this time is as follows: Of the fifteen living patients the sputum is negative for tubercle bacilli in twelve cases, is positive in two cases, and one case is too recent for evaluation. Of the twelve cases in which the sputum is negative, six cases that have been followed the longest since operation are negative on cultures, whereas in the six more recent cases the sputum is negative on concentration.

So far thoracoplasty has been performed following lobectomy in only one case. This thoracoplasty was performed for a residual cavity following an apical staphylococcus empyema which showed no evidence of being tuberculous. Two of the fifteen living patients have had a late tuberculous complication. One patient who had a lobectomy of the right upper and middle lobe with an uneventful and uncomplicated postoperative course developed a contralteral pleurisy with effusion several months after operation. The effusion has since cleared completely and there is no evidence of a new parenchymal lesion.

The second patient signed out of the hospital against advice five weeks after an uncomplicated lobectomy, and immediately returned to an active life with much exercise. Several months later she had hemoptyses. Roentgenograms revealed reactivation of the pre-existing tuberculosis in the apex of the lower lobe on the side of operation. The sputum again became positive.

The general condition of all the patients, with the exception of the two with positive sputum, may be classified as good to excellent. Patients in several of the early cases are working. The two patients with positive sputum have no draining wounds and are in satisfactory general condition; both require a partial thoracoplasty.

DISCUSSION

The selection of the type of case for lobectomy, especially in relation to the degree of activity of the disease at the time of operation, may considerably influence the result. Because of the relatively limited experience we have had so far, there are numerous unsolved problems concerning the selection of cases. At present we do not know how much the hazard of lobectomy is increased if the tuberculosis is moderately active. In some cases in which the tuberculosis was clinically active, the response following a lobectomy was gratifying.

We consider the anesthesia to play a very important role in the results of pulmonary resection in tuberculosis. It is not so much the anesthetic agent which is employed as the ability of the anesthetist to maintain a clear unobstructed airway and lessen the hazard of bronchiogenic spread of the tuberculosis.

If tuberculous tissue is traversed during the surgical dissection, what complications may be expected? Undoubtedly the immunologic state of the tuberculosis will considerably influence the result. It is readily conceivable that whereas very slight contamination of the operative field with tuberculous tissue may result in no sequelae of importance in a patient with good resistance, a similar contamination in a patient with unstable tuberculosis may cause marked systemic and local reactions. The number of patients with various degrees of clinical activity of the tuberculous process that have been operated upon to date does not permit definite conclusions to be drawn. In several instances an extremely small amount of tuberculous tissue was traversed in the division of an incomplete fissure without evidence of postoperative complications, except in one case. Associated with this problem is the question of incomplete interlobar fissures which deserves special consideration.

The extent to which the various pulmonary lobes are anatomically separated by fissures is of real concern in lobectomy for pulmonary tuberculosis. Of particular importance is the high incidence of incomplete fissure between the upper and lower lobes posteriorly. Pulmonary tuberculosis is far more common in the upper lobe than in

other portions of the lung, but, associated with the process in the upper lobe, tuberculosis is frequently encountered in the apex of the lower lobe. This distribution of tuberculosis is unfortunate from the standpoint of lobectomy. The long fissure between the upper and lower lobes is usually incomplete posteriorly, just where tuberculous lesions are most frequent. Therefore, if the surgeon divides the pulmonary tissue in the area of the anatomically incomplete fissure, there is a considerable chance that tuberculous tissue will be traversed. The management of cases in which there is evident tuberculosis at the site of the incomplete fissure has remained a major problem. In three instances in which such a finding was present at operation and pneumonectomy was either contraindicated or considered inadvisable, the operation of lobectomy was abandoned and some other procedure substituted. In some instances in which the preoperative roentgenograms suggested the possibility of tuberculous tissue extending from the upper to the lower lobe, it was decided preoperatively to perform a lobectomy only if this could be done without traversing an obviously tuberculous lung. In one such instance merely an open pneumonolysis was done with excellent results. If the pleural space is obliterated by adhesions it may be possible, without freeing the lung, to determine readily that lobectomy is not feasible because of tuberculous involvement at the site of an incomplete fissure. Under these circumstances a first stage thoracoplasty instead of lobectomy might be performed at the same operation.

Because of the great frequency of tuberculous involvement of the apex of the lower lobe, in association with disease in the upper lobe, it is important to decide prior to operation whether all the cavities are limited to the upper lobe. We have not knowingly recommended a lobectomy in the presence of cavitation in any of the remaining pulmonary tissue on the side of operation. A problem of immediate concern, however, has been the presence of a cavity or caseous foci at the site of an anatomically incomplete fissure. Posteroanterior roentgenograms of the chest give incomplete information concerning the location of tuberculous cavities or areas of caseation. A lateral film is indispensable in deciding whether some lesions are located in the upper lobe or in the upper portion of the lower lobe. Because the level of the interlobar fissure is altered by pathologic processes which cause a shrinkage of one lobe or segment of the lung with secondary hyperinflation of another portion of the lung, it is not possible merely from the location of the lesion as seen on the lateral roentgenogram to be certain whether a shadow is just above or below the interlobar fissure. Posteroanterior or anteroposterior tomographs have been of some aid in localization, but doubt may still remain concerning the exact site of the fissure. Recently, however, we have employed lateral tomographs and these films have been of real aid. The lateral tomograph not infrequently depicts the interlobar fissure as a well-defined

line on at least one of the sectional films. This interlobar line may be seen on the film at the same level at which the major tuberculous pathology is demonstrated. The fact that the interlobar fissure is demonstrated as a well-defined line on one of the tomographs does not mean that the fissure is obliterated by adhesions. A cavity which appears on the film in such close proximity to the fissure that the area of the cavity immediately adjacent to the fissure is even somewhat flattened may not necessarily produce any difficulties at operation. Lateral tomographs may also give additional information concerning the location of areas of caseation. Caseous foci which can be readily demonstrated on the routine posteroanterior film may not be clearly demonstrable on lateral films, either with routine or Potter-Bucky type of exposure. Some of the sectional films of the tomograph, however, may clearly demonstrate and localize such caseous areas.

In the majority of instances in which removal of the right upper lobe was planned it seemed advisable at the time of operation to also remove the middle lobe. As the fissure between the upper and middle lobe is usually rudimentary, considerable pulmonary tissue must be transected in order to remove the upper lobe alone. Since tuberculous foci are usually present in this area it seemed safer to sacrifice a small amount of additional pulmonary tissue rather than accept a greater risk of contamination of the pleural space with tuberculosis. In most instances considerable tuberculosis was present throughout the middle lobe, in addition to the involvement in the region of the incomplete fissure.

Should lobectomy be followed by a partial thoracoplasty? Following lobectomy there is a variable amount of hyperinflation of the remaining pulmonary tissue on the side of operation. The degree of hyperinflation which results will depend chiefly on the volume of pulmonary tissue removed. From follow-up observations on bronchiectasis cases treated with lobectomy, it would seem that the hyperinflation of the remaining lobe in itself is not particularly detrimental. The problem may vary depending on the lobe resected. Since in most cases of pulmonary tuberculosis the disease is not entirely limited to one lobe, some tuberculous foci will still be present in the remaining lobe following lobectomy. Hyperinflation might possibly increase the chance of reactivation or facilitate the breakdown of such a tuberculous focus. It therefore remains to be determined by follow-up observation over a period of years whether hyperinflation of the remaining lobe will have a significant detrimental effect. When spontaneous healing with fibrosis occurs in upper lobe tuberculosis there is marked shrinkage of the upper lobe and compensatory hyperinflation of the lower lobe. The end result of this process is little different from that occurring after lobectomy of the upper lobe. The future will determine whether or not an apical thoracoplasty should follow lobectomy of the

upper lobe in tuberculosis. Hyperinflation and pulmonary emphysema are much more a problem following pneumonectomy than following lobectomy because of the greater loss of pulmonary tissue associated with pneumonectomy and because of the disturbances associated with mediastinal deviation. One patient in our series had a reactivation of pre-existing tuberculous areas in the apex of the lower lobe following lobectomy of the upper lobe. It should be pointed out, however, that this patient left the hospital against advice and resumed an active life five weeks following lobectomy.

In spite of the fact that the operation of lobectomy is prolonged and involves extensive intrapleural manipulation, the postoperative reaction is sometimes less than that seen after a first stage thoracoplasty. Two possible explanations may be considered. Thoracoplasty is associated with considerable disturbance of respiratory mechanics which also interferes with the natural means of bronchial drainage. Paradoxical motion of the decostalized portion of the chest wall may be a factor in postoperative bronchiogenic spread of the tuberculous process. An indication that the abnormal mobility of the thoracic wall is perhaps more important a factor than the collapse of tuberculous pulmonary tissue is suggested by the smoother early postoperative course following an extrapleural pneumothorax as contrasted to a thoracoplasty with similar amount of pulmonary collapse. As only two ribs are divided during lobectomy and the chest cage is again stable at the conclusion of the operative procedure, no paradoxical motion is present following lobectomy. The most serious alteration in respiratory function immediately following operation is due to reflex splinting because of pain. If considerable pain is present the reflex impairment in ventilation on the side of operation may be considerable, but with proper closure of the chest wall and adequate but not oversedation in the postoperative period, respiratory disturbances may be minimized.

A second possible explanation of the favorable postoperative reaction following an uncomplicated lobectomy is concerned with the removal of the major portion of the tuberculous tissue. The problem of maintaining cavity drainage in the postoperative period is eliminated. Therefore, the chances of bronchiogenic spread occurring after operation should be less than after thoracoplasty, although the risk of spread during operation is definitely greater in the case of lobectomy.

From personal observation of the postoperative course of a large series of lobectomies for bronchiectasis, we felt that early re-expansion of the remaining lobe greatly reduced postoperative morbidity and even mortality. Early obliteration of the pleural space was considered the best assurance against postoperative empyema. When we first performed lobectomies for pulmonary tuberculosis we sought early obliteration of the pleural space by re-expansion of the remaining lobe

and diaphragmatic paralysis. Most of the lobectomies were performed for upper lobe disease, and expansion of the lower lobe so as to completely fill the pleural space was often a gradual process. In some instances the remaining pulmonary tissue did not completely fill the pleural space until several months following lobectomy. It gradually became evident that a residual pneumothorax space for a period of time following lobectomy was not necessarily a great disadvantage.

The results obtained to date justify further investigation of pulmonary resection in selected cases of tuberculosis. The type of case to be chosen for operation is still largely an unsolved problem. Moreover, it must be fully appreciated that unless the surgical setup is almost ideal, the results of lobectomy in tuberculosis will probably be disastrous. Although one death in sixteen cases may not seem to be a high mortality for pulmonary resection in tuberculosis, this mortality percentage is actually four times as high as one of us has reported for resection in bronchiectasis (one death in sixty-four cases). Therefore, unless lobectomy and pneumonectomy for nontuberculous infection can be performed with a low morbidity and mortality, the results of resections in the presence of active tuberculosis may well be disastrous.

SUMMARY

A group of sixteen consecutive cases in which a hilar dissection type of lobectomy was performed as the primary surgical procedure for pulmonary tuberculosis is analyzed. All patients had a positive sputum prior to operation. The details of the operative procedure which are considered important are discussed. The postoperative complications and results are indicated. One fatality occurred from contralateral spread of the tuberculosis.

The authors gratefully acknowledge the valued cooperation of Dr. Richard Bennett and Dr. McLeod Riggins, Directors of the Medical Services, Triboro Hospital.

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(*See discussion on page* 45.)

PRIMARY UPPER LOBECTOMY VERSUS MODERN SELECTIVE THORACOPLASTY IN THE TREATMENT OF TUBERCULOSIS

Physiopathologic Considerations

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SCOPE

THE modern selective thoracoplasty and its role in the treatment of pulmonary tuberculosis are well established. This is not yet true of primary upper lobectomy. It is generally believed that lobectomy should be secondary[15] to a thoracoplasty failure, but recently primary lobectomy has appealed to both patient and surgeon. It would be premature at this time to compare these two procedures from the standpoint of hospital days, sputum, conversion, or mortality rates, but since the pulmonary dynamics are significantly altered by these procedures, the physiopathologic features of each will be considered in light of newer knowledge.

The correct decision in regard to the therapeutic choice between lobectomy and thoracoplasty is dependent upon one's goal. At one time obesity was the therapeutic objective, because tuberculosis was a consuming disease, and though the patient may not have survived the infection, he was well nourished to the end. Later, a negative smear was considered the measure of success, but soon this standard was replaced by more refined techniques, until now we have a dual objective: the patient must be not only a bacteriologic cure, but must make a satisfactory sociologic adjustment as well. This idea was suggested by Churchill[11] when he wrote that because of prolonged invalidism the patient's personality is often converted with his sputum. It may be said then that since every tuberculous patient has both diseased and healthy areas in his lungs, it is the diseased segment which takes him out of society and it is the healthy component which makes his return successful. The therapeutic choice should be based, therefore, on that procedure which not only consistently controls the diseased focus, but permanently preserves the function of the healthy lung as well.

This report purposely avoids a discussion of pneumonectomy and lower lobectomy which would appear to be separate and distinct problems. Suffice it to say that collapse therapy is moderately successful in the upper half of the chest, but quite unsuccessful in the lower half.

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DEFINITION

Primary upper lobectomy consists of the meticulous removal of the lobe by individual ligation of the vessels and plastic closure of the bronchus. This obviously implies that the disease be limited to the upper lobe and that obliteration of the pleural cavity be immediately attempted by rapid overexpansion of the remaining lobe or lobes.

The modern selective thoracoplasty of comparable dimensions consists of subperiosteal removal of the first two ribs and graduated segments of ribs three to five or three to six to allow for concentric relaxation of the lobe. The operation is usually done in two stages and, when indicated, vertical relaxation may be obtained by a small Semb apicolysis, but the removal of the transverse processes, the first two cartilages, and the lower angle of the scapula is optional. Such collapse extends downward to the third rib anteriorly and the sixth rib posteriorly without encroaching upon the right middle lobe, the lingula of the left upper lobe, or either of the lower lobes. That the apex of the lower lobe is nearer the level of the sixth rib posteriorly rather than the fourth is an anatomic fact only recently disclosed by Brock[7] in London. Therefore, a five- or six-rib modern selective thoracoplasty and an upper lobectomy are both designed to control lesions chiefly confined to the upper lobe.

GENERAL CONSIDERATIONS

Pulmonary tuberculosis is always bilateral[14] or should be considered so even though the scattered minor foci are inactive or not visible by x-ray. If an "open" lesion is present on one side it is not difficult to visualize the mechanism by which contralateral seeding occurs, since the trachea serves both lungs. Total excision of diseased areas is therefore impossible, for only the active major focus can be removed, but when this has been done the remaining parenchyma with its potentially active foci become our major interest. These, however, are of interest as influenced by alterations in the pulmonary dynamics after thoracoplasty or lobectomy.

Another probable truth is that endobronchial tuberculosis is present in all cases of tuberculosis with cavitation.[25, 28] Auerbach and Green[4] point out that these "Bronchi almost invariably show the same tuberculous process as that seen in their respective cavities." Though clinically we have been aware of endobronchial tuberculosis only in the last ten years, it has been present always, though it may have been beneath the mucosa or just beyond the view of the bronchoscopist. The significance of this complication is directly proportional to (1) the kind of endobronchial lesion, (2) the size of the bronchus involved, and (3) the degree of obstruction. Obviously, a small submucous tubercle is not as serious as an ulcerative lesion which circumscribes and almost completely obstructs a large bronchus. An ulcerative endobronchial lesion of moderate or extreme severity implies severe damage distal to it in the

form of (1) obstructive emphysema, (2) suppuration, (3) atelectasis, or (4) tension cavities. A definitive form of therapy is indicated, therefore, if one or more of these complications exist.

Thoracoplasty had met with considerable success before we were aware of the presence of endobronchial tuberculosis and now we intentionally do thoracoplasties over certain types of lesions in the major bronchi (visible at bronchoscopy) and with good results as reported by Alexander,[2] Tuttle,[26] Chamberlain and Gordon.[10] In one of our most severe cases (E. R.) the patient could not be bronchoscoped because of hoarseness and laryngeal tuberculosis, yet the indications for thoracoplasty were present and it was recommended, based on the philosophy that control of the pulmonary focus will very often control the bronchial or laryngeal complication. It was done with excellent results and bronchoscopy before the patient's discharge revealed an old healed tracheal lesion which had reduced the tracheal lumen by one-third. Endobronchial tuberculosis, often cited as an indication for lobectomy, will respond to collapse by thoracoplasty in at least 75 per cent of the cases.[2, 10, 26] In the few thoracoplasty failures a lobectomy can still be done and with less risk or without overdistention of the remaining lung.

We must also keep in mind that in every case of tuberculosis there are both the obstructive (endobronchial disease) and overdistention types of emphysema, which are directly proportional to the amount and duration of the tuberculosis. When the diseased area heals by cicatricial contraction the normal elastic lung compensates by overexpansion and if the lesion is small only a few alveoli become dilated to form a patchy or localized area of emphysema (Laennec), but if an entire lobe or more is destroyed, these compensatory factors are taxed to the limit and Sir William Osler writes,[21] "At first this distention is a simple physiological process and the alveolar walls are stretched, but not atrophied. Ultimately, however, in many cases they waste and the contiguous air cells fuse, producing a true emphysema." If this concept is accepted then as the tuberculosis heals we simply replace one disease with another, namely, emphysema for tuberculosis.

In the treatment of pulmonary tuberculosis by either of these two procedures (lobectomy or thoracoplasty), consideration must be given not only to the major pathologic focus but to the physiologic status of the remaining parenchyma as well. Conversion of the sputum is important, but not at the expense of respiratory invalidism. Reduction in function due to pathologic destruction of tissue is self-explanatory, but reduction in function by alterations in the respiratory physiology is due, among other things, to (1) ventilatory disturbance or (2) alterations in the alveolar exchange of gases. Ventilation, or movement of the air in and out of the chest, is accomplished mainly by the action of the diaphragm and lower six ribs but the ventilatory role of the upper ribs is comparatively slight. On the other hand, the exchange of alveolar gases is dependent upon both the ventilatory factors and the integrity of the

alveolar unit, and even though the alveoli are normal they may be of little usefulness if the ventilatory mechanism is not intact, and conversely the bellows action of the chest may be a futile effort if the alveolar unit is in disorder.

THE PHYSIOPATHOLOGY OF THE MODERN THORACOPLASTY

As early as 1822, James Carson[8] said of tuberculosis, "If this disease is to be cured—it must be accomplished by mechanical means" and since then innumerable surgical innovations have appeared based on various combinations of five fundamental principles, namely (1) drainage, (2) immobility, (3) relaxation, (4) compression, and (5) resection. Drainage (Monaldi or open) is still used in selected cases, but *immobility* of the chest through intercostal neurectomy, etc., has very limited usefulness. Pneumothorax is the classical example of therapy based essentially upon *relaxation* but by contrast the plombage operations (including extrapleural air) were dependent mainly upon *compression* for their effect and recently, pulmonary *resection,* once discarded, is enjoying an interesting though debatable revival.

The modern selective thoracoplasty combines at least three, and possibly four, of these basic principles. Relaxation is obtained by the elastic recoil of the lung after rib resection and apicolysis; compression results from the weight of the scapula and the extra fascial fluid which develops in the subscapular space; drainage occurs via the endobronchial route; and when rib regeneration is complete immobility of the diseased area is accomplished.

Subsequent to a modern selective thoracoplasty the respiratory function may be reduced, unchanged, or improved. Bronchospirometric determinations were done on twelve patients before and after a modern selective six-rib thoracoplasty by Wright and Woodruff[27] and it was shown that three patients had a decrease in function, six patients had no significant change, and three patients showed definite improvement. In other words 25 per cent had a reduction in function and 75 per cent showed no change or were improved. These findings may be explained by the fact that though a reduction in function occurred in the area of collapse, respiratory efficiency or economy[18] was improved elsewhere through restoration of the normal pulmonary dynamics. In the three patients showing respiratory reduction it is possible that irreversible changes had occurred in the uncollapsed area because of previous disease or prolonged overdistention.

These findings are not difficult to accept when one recalls that (1) ventilation is poor in the upper half of the chest, (2) pulmonary tissue is actually lost by the inflammatory disease, and (3) the tissue which appears to be normal by x-ray may be very inefficient if stagnation of air occurs through the presence of endobronchial disease. Therefore, the slight amount of function in such a lobe is easily compensated for by the improvement in the remaining parenchyma.

PHYSIOPATHOLOGY OF PRIMARY UPPER LOBECTOMY

Primary upper lobectomy, however, is dependent upon none of the basic principles listed. In contrast to the modern selective thoracoplasty, resection of the upper lobe has only one objective, namely, to control the major focus with no consideration for the pathology or physiology of the acutely overdistended remaining parenchyma. From a pathologic viewpoint we must consider (1) the effect of the overdistended lung upon the remaining "healed" foci or foci of "low-grade activity," and (2) the effect of overdistention upon the resistance of the lung to new disease or reactivation; while from a physiologic standpoint we must determine (1) the role of overdistention upon respiratory function, and (2) the degree and duration of overdistention necessary to produce emphysema (rupture of the alveolar septae).

The effect of overdistention upon the remaining "healed" foci is difficult to determine, because it is difficult to know when a lesion of low-grade activity is healed. It may be hypothetically stated that if the lesion is really healed then overdistention is not likely to influence it, but if low-grade activity is present then overdistention is contraindicated since we have all seen the pneumothorax case which reactivated upon re-expansion because complete healing had not occurred. It is also suggested that the "spreads" which occur during or after re-expansion of a pneumothorax may be reactivation of the disease due to the overdistention of an indolent but "unhealed" focus. It was noted in reviewing twenty-five Monaldi cases with Dr. E. F. Butler that the disease elsewhere in the chest frequently progressed, especially in those cases where the cavity under treatment was *large* and closure necessitated overdistention of the remaining parenchyma. Yet all of us have reviewed with amazement apparent cures in which both upper lobes were destroyed by disease and retracted into the thoracic vaults, which resulted in extreme overdistention of the remaining lobes; and also patients with almost total atelectasis on one side from endobronchial tuberculosis, with marked herniation of the mediastinum and rather severe overdistention of the remaining lung. The answer is perhaps twofold: (1) such cases are exceptions to the rule and (2) the overdistention in such cases was a very slow and gradual process in contrast to the rapid overdistention subsequent to lobectomy.

Should pulmonary tuberculosis occur in the remaining overdistended parenchyma it is less likely to heal or to remain permanently healed. Andrus[3] and others have demonstrated clearly some of the important factors in the pathogenesis of cavities, by pointing out that once destruction of the parenchyma occurs in a focal area, then the supporting elements retract in all directions because of the negative intrapleural pressure and the innate elastic tension of the lung. Subsequent to lobectomy it seems reasonable to expect the same dynamic behavior, but with greater intensity because during acute re-expansion of the lung

the negative pressure may become very great. Of further significance in healing is the diminution of bronchial peristalsis since the smaller, thin-walled bronchioles and even the large bronchi (visible by bronchoscopy) may lose some of their normal mobility. Brock[6] has emphasized repeatedly the importance of maintaining normal "peristaltoid" movements of the bronchial tree if spreads and reinfection are to be avoided.

That pulmonary function is actually reduced by overdistention is shown by the respiratory physiologists. Though most of the studies were done on patients before and after pneumonectomy it seems logical to assume that the same principles will be in effect subsequent to upper lobectomy, but to a lesser degree. Therefore, one may expect an increase in residual air, an elevation of midcapacity, and a decrease in maximum minute ventilation, in reserve air, and vital capacity. These same factors are all present in the patient with obstructive emphysema, asthma, or silicosis. Though in tuberculosis one is willing to sacrifice the function of the diseased lobe to obtain a cure, an additional loss through overdistention and its complications is undesirable. That overdistention after lobectomy can actually produce true emphysema (rupture of the alveolar septa, etc.) in the adult human being is a probable truth but based upon experimental fact. Cohn,[13] Bremer,[5] Longacre,[19] and others have shown that overdistention of the lungs in *young* rats, cats, and dogs, respectively, will not cause true emphysema. Rienhoff[24] found overdistention without emphysema after pneumonectomy in dogs, but his experiments were thought to be relatively acute when compared to those of Longacre, who performed pneumonectomies in adult dogs and not only presented histologic evidence of emphysema, but physiologic proof as well, four years later. Prinzmetal,[23] Campbell,[9] and others were able to produce the histologic picture of emphysema in a variety of animals, including monkeys, by marked reduction in atmospheric pressures. Paine[22] rather ingeniously "pleated" the diaphragm of adult dogs to enlarge the thoracic cage and produced emphysema. Christie,[12] a veteran worker in this field, recently said that overdistention will not cause emphysema but he definitely points out that he refers to "Chronic vesicular or hypertrophic emphysema—it being understood that acute emphysema, senile emphysema, and localized emphysema are probably separate and distinct entities." It would seem, therefore, that the differences of opinion in the literature may be based upon (1) the type of emphysema under discussion and (2) the duration of etiologic factors.

That the removal of one lobe is sufficient to produce "overdistention emphysema" in dogs was shown by Adams,[1] Kountz and Alexander,[16] Nissen,[20] and others. Laennec[17] describes a patient with "The air cells evidently enlarged over the whole surface of the lung because of kyphosis" and a carnified right lower lobe which was "indurated, and posteriorly . . . as hard as liver." I have operated upon a similar patient with tuberculosis[29] but without the kyphosis and found (1)

atelectasis of the right lower lobe due to almost complete obstruction of the bronchus (endobronchial disease), (2) obstructive emphysema in the middle lobe due to partial obstruction from endobronchial disease, and (3) overdistention emphysema in the right upper lobe where a variable amount of tuberculosis had existed in the past. The pneumonectomy was made technically difficult by the failure of the upper lobe and middle lobe to collapse due to the emphysema.

The so-called "good chronic" who heals or tends to heal his tuberculosis with or without medical attendance is the best example of all of these physiopathologic factors at work. He is usually in late middle life, quite comfortable at rest, but has developed the habit of talking in short sentences, at the end of which he takes a quick inspiratory gasp because of his low respiratory reserve. On examination of such patients there is: (1) a reduction in the size of the chest, (2) decrease in costal movement or expandibility, (3) contraction of the diseased area, and (4) compensatory distention of the remaining lobes or lung.

Reduction in the size of the chest is manifest by atrophy of the accessory muscles of respiration, narrowing of the intercostal spaces, elevation of the diaphragm, scoliosis, and shift of the mediastinum toward the side of maximal disease. No reduction in the size of the chest occurs when a small amount of lung is destroyed, since the surrounding parenchyma easily distends to compensate as healing occurs, but when the amount of disease is extensive and the entire lobe or more is destroyed, there is a limit to this distensibility and the previously mentioned compensatory factors come into play.

Decreased movement (expandibility) of the thoracic cage is noted by direct observation at fluoroscopy, but it is especially conspicuous at operation with the scapula elevated since under these conditions the ribs over the diseased area scarcely move when compared with the movement in the nondiseased areas. Such immobility is due to the inelasticity of the old underlying disease (tuberculosis and emphysema), to the pleuritis, peripleuritis, and atrophy of the intercostal muscles. The ventilatory loss by this immobility is of little significance since the underlying diseased lobe is an ineffective respiratory unit, but subsequent to lobectomy when chest wall activity is again desirable it may not return.

Contraction of the diseased area is the usual result when healing tends to occur. In the far-advanced case it is mainly responsible for the immobility and diminution in the size of the thoracic cage. It is recognized best in serial x-rays by the movement upward of the interlobar fissure, elevation of the hilar structures, and shift of the trachea toward the diseased side (palpation in the suprasternal notch).

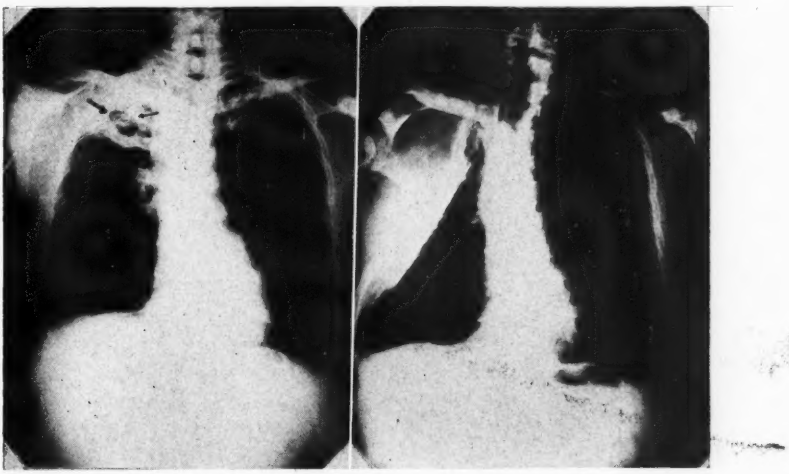
Compensatory distention of the remaining normal parenchyma is the sequel to every large or microscopic insult that occurs in the adult lung, if healing occurs by contraction. Again it may be said that when

minimal tuberculosis is present the overdistention is localized and of little significance, but if the disease is extensive the overdistention may be generalized and not only involves the lobes on the same side but the contralateral lung as well through mediastinal attraction.

When the "good chronic" reaches his pathologic and physiologic limits, one sees at autopsy both obstructive and overdistention types of emphysema complicating the tuberculosis and it is the emphysema, probably, which accounts for much of the respiratory embarrassment.

DISCUSSION

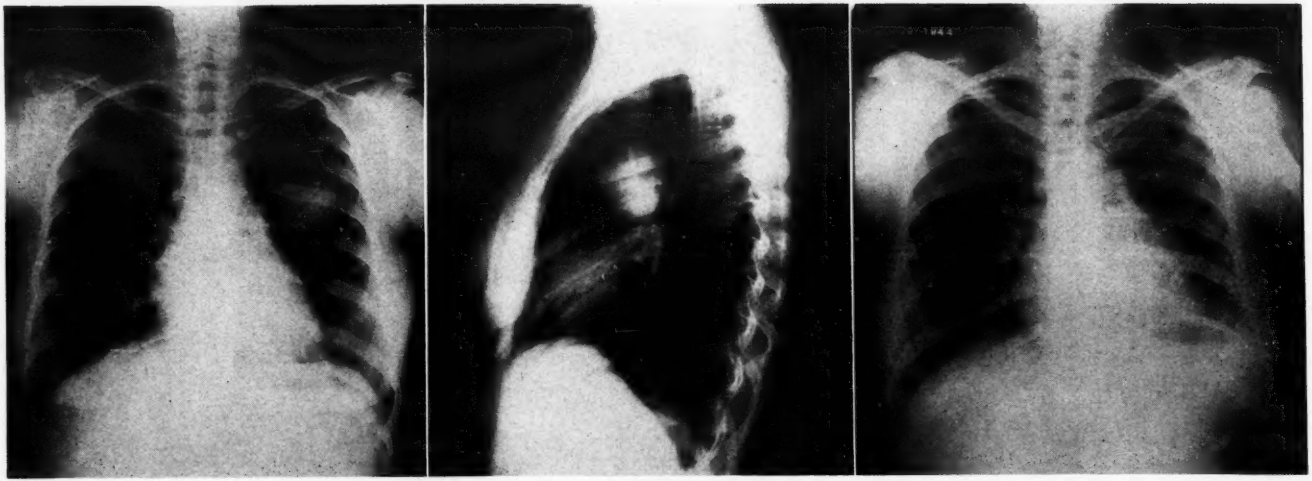
Primary upper lobectomy, paradoxical as it may seem, may prove to be less physiologic than the modern selective thoracoplasty, but it is not implied that every patient who has a primary upper lobectomy will become a respiratory cripple. Repeated bronchospirometric determinations done on a few patients two years after the thoracoplasty[27] have shown a progressive improvement in respiratory function when compared with the determinations made just before and relatively soon after operation. However, if overdistention is the precursor to slow but progressive emphysema then it is reasonable to predict that subsequent to an upper lobectomy the respiratory function may be gradually reduced.



A. *B.*

Fig. 1 (Case 1).—*A*, Preoperative posteroanterior view; *B*, postoperative view after six-rib thoracoplasty and partial scapulectomy.

CASE 1.—A 44-year-old married, white, ammunition worker entered the hospital in good general condition, because of far-advanced pulmonary tuberculosis of which the patient was scarcely aware. Examination was consistent with the roentgenogram and though pneumothorax was under consideration the patient requested a thoracoplasty. No



A. *B.* *C.*

Fig. 2 (Case 2).—*A*, preoperative posteroanterior view; *B*, preoperative lateral view; *C*, postoperative posteroanterior view of overdistended left lower lobe one year after left upper lobectomy.

endobronchial disease was in the major bronchi, but an expiratory wheeze could be demonstrated. A two-stage six-rib thoracoplasty and partial scapulectomy were done. He was discharged negative on culture one year later and has been working at his original position since. Bronchospirometric determinations by Wright and Woodruff one year after his return to work revealed that his maximum minute ventilation was 89 liters per minute, vital capacity 2.5 liters, and the ventilation in the right lung 47.5 per cent with 52.5 per cent on the left side. Oxygen consumption, though not quite as good, was 40 and 60 per cent, respectively. This case is presented for comparison with the next case.

CASE 2.—A 30-year-old housewife and defense worker, without symptoms, had a chest x-ray taken because of a persistent low-grade fever subsequent to a miscarriage. A discrete round shadow was found in the left upper lobe. A left upper lobectomy was done by individual ligation technique and plastic closure of the bronchus was followed by excellent re-expansion and an uneventful recovery. The patient has lived a normal unrestricted life since and one year after operation a bronchospirometric determination was done. Her maximum minute ventilation was 99 liters per minute and vital capacity 2.46 liters. The ventilation on the right side was 58 per cent and on the left 42 per cent, while oxygen consumption was 70 and 30 per cent, respectively.

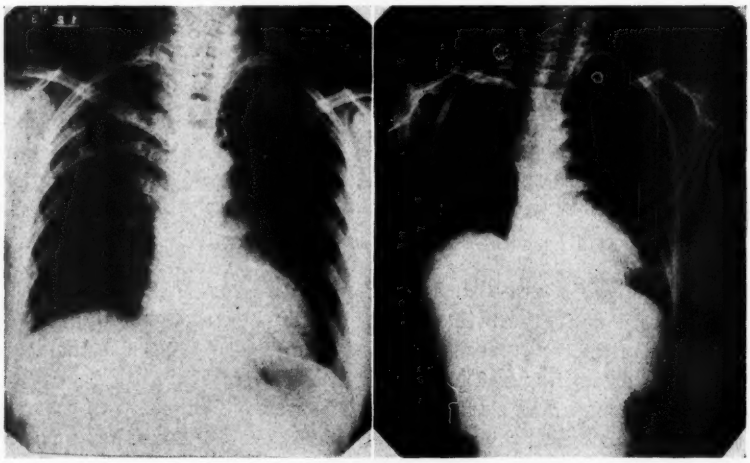
Discussion of Cases 1 and 2.—Preoperative controls were not done but Cases 1 and 2 have in common, disease limited to the upper lobe and similar figures from functional studies. Of interest are the facts that the patient in Case 1 had old disease with tracheal shift, narrowing of the interspace and elevation of the interlobar fissure due to contraction of the diseased area, and overdistention of the remaining parenchyma. He was not old but his disease was old and at operation much of the elastic recoil had been lost, necessitating the removal of larger segments of ribs and more radical collapse than is usual. This case (Case 1) is presented as a good bacteriologic result, but only a fair functional result, yet in comparison with an ideal lobectomy case (Case 2), the functional result is slightly better.

CASE 3.—A 35-year-old telephone operator had a diagnosis of tuberculosis, and was treated by bed rest for two years. A positive sputum was found only once but a recommendation of lobectomy was made because of pulmonary suppuration in the right upper lobe also. After this operation the patient developed a nontuberculous empyema which was drained anteriorly and later closed with a muscle flap. She was then symptom-free for six months, at which time she began to have hemoptyses. Bronchoscopy revealed a kinked right lower lobe bronchus from the ascent of the lower lobe into the thoracic vault. A granuloma

developed at the point of kinking and was removed with biopsy forceps and the base treated with $AgNO_3$ four times before it failed to return.

Bronchospirometric determinations recently, by Wright and Woodruff, revealed that the maximum minute ventilation was 62 liters per minute, and the vital capacity 1.3 liters. Ventilation on the right was 40 per cent and on the left 60 per cent, but the unexpected finding was the oxygen consumption of 10 on the right side and 90 per cent on the left.

The reduction in function was thought due to (1) the formation of a small lung abscess at the apex of the remaining right lower lobe, (2) prolonged overdistention of this lobe, and (3) obstructive emphysema from kinking and the formation of the small granuloma.



A. *B.*

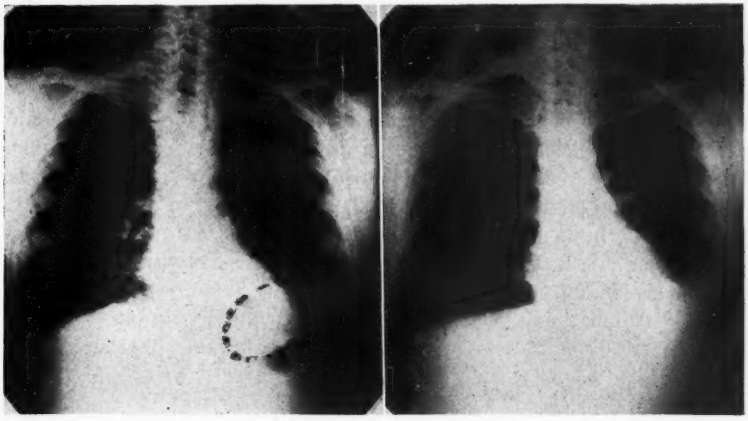
Fig. 3 (Case 3).—*A*, preoperative view of cavity and fluid level of two years' duration; *B*, postoperative view over two years after right upper lobectomy.

CASE 4.—A 30-year-old singer and English instructor was found, at a routine tuberculosis school survey, to have a discrete tumor in the left lower lobe. No symptoms were associated and the pathologic diagnosis after left lower lobectomy was tuberculoma. His convalescence was uneventful and almost four years later a bronchospirometric determination showed a maximum ventilation of 155 liters per minute, vital capacity 4.06 liters. The ventilation on the right side was 65 per cent, left 35 per cent. Oxygen consumption was 71 and 29 per cent, respectively. The most significant finding, however, was his low arterial saturation—87 per cent.

Discussion.—The case is presented because the lobectomy had been done four years prior to the bronchospirometric determination and

though little significance can be attached to one case the low arterial saturation suggests respiratory inefficiency.

In forty-six consecutive thoracoplasties with partial scapulectomies done in the last four years on patients whose disease was limited to the upper lobe or upper lobes (three were bilateral operations), the sputum was converted by concentrated methods of examination in 80 per cent of the cases. Of the nine failures, one was a bilateral operation; the second patient was to have a bilateral operation but left against advice. A third patient was discharged for disciplinary reasons. The fourth, though clinically well, had a bilateral operation only recently; the fifth had a good result from thoracoplasty on one side and though it was negative for some time an old cavity reopened in the contralateral lung. The sixth operation was done over an apical tuberculous empyema with a bronchopleural fistula; the seventh is as often negative as positive; and the eighth and ninth are outright failures. There was only one death in the series (2 per cent) and this patient did not have a scapulectomy, though had the initial operation been successful a scapulectomy would have been done.



A. *B.*

Fig. 4 (Case 4).—*A*, preoperative view of tuberculoma; *B*, postoperative view four years after lower lobectomy.

There are many factors which have not been discussed. The cardiac reserve, the shape of the chest, the age of the patient, the degree of abdominal obesity, and the general muscular tone are all factors which exert a profound influence upon respiratory function. A young male adult with normal rib obliquity, and thin abdomen, good muscular tone, and exceptional pulmonary elasticity might tolerate a lobectomy with little loss of function, but this could not be expected of an older person with thoracic fixation, horizontal ribs, a fat abdomen, and deficient pulmonary elasticity.

CONCLUSIONS

1. The choice of therapy between primary upper lobectomy and upper selective thoracoplasty is dependent upon that one which consistently controls the diseased focus and permanently preserves the function of the remaining healthy lung.

2. Tuberculosis is always bilateral, though not always active on both sides. Overdistention after lobectomy is believed to be an undesirable physiologic state for a lung harboring a lesion of low-grade activity.

3. Endobronchial tuberculosis is present in all cases with cavitation and its significance is essentially dependent upon the degree of bronchial obstruction which may cause obstructive emphysema, suppuration, atelectasis, and tension cavities. Thoracoplasty is successful in 75 per cent of the cases in which the diseased bronchus is visible by bronchoscopy.

4. Emphysema is present in all cases of pulmonary tuberculosis, is due to overdistention or obstruction (endobronchial disease), and is proportional to the duration and stage of the disease. The resulting dyspnea often dominates the clinical picture in far-advanced cases.

5. Thoracoplasty is successful because it utilizes four of the five basic principles of therapy in this disease: (1) drainage (bronchial), (2) immobility, (3) relaxation, and (4) compression. The fifth principle, resection, is reserved for its failures.

6. Primary upper lobectomy excises only the active major focus and causes overdistention which (1) is probably a precursor to emphysema, (2) may cause reactivation of latent foci in the overdistended lobes, and (3) leaves these foci in a poor state for healing or self-protection.

7. Primary upper lobectomy may prove to be a less physiologic procedure than the modern selective six-rib thoracoplasty since the latter shows a significant reduction in function in only 25 per cent of the cases.

8. Upper lobectomy should be secondary to the thoracoplasty failure and has not been difficult to perform when adequate exposure is obtained.

The author is indebted to Dr. George Wright and Dr. Warner Woodruff who performed the bronchospirometric determinations and contributed a great deal to a better physiologic understanding of this problem. Much credit is also due the medical staffs of the State and County Hospitals who referred these patients and shared in the responsibility of their pre- and postoperative care.

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DISCUSSION ON "PULMONARY RESECTION IN THE TREATMENT OF TUBERCULOSIS" BY DR. FRANK S. DOLLEY*; "TOTAL AND PARTIAL PNEUMONECTOMY IN THE TREATMENT OF PULMONARY TUBERCULOSIS" BY DR. ROBERT M. JANES†; "LOBECTOMY FOR PULMONARY TUBERCULOSIS" BY DR. HERBERT C. MAIER AND DR. ROBERT KLOPSTOCK‡; AND "PRIMARY UPPER LOBECTOMY VERSUS MODERN SELECTIVE THORACOPLASTY IN THE TREATMENT OF TUBERCULOSIS" BY MAJOR J. MAXWELL CHAMBERLAIN

CHARLES P. BAILEY, Jenkintown, Pa.—We believe that the low mortality and high efficiency of thoracoplasty in properly indicated cases warrants no use of any new procedure in such cases. Dr. Chamberlain has shown beautifully that in the properly selected cases thoracoplasty is a very satisfactory procedure. I believe the indications for resection in pulmonary tuberculosis are those cases where collapse therapy has failed or, in all probability, in reasonable clinical judgment, will fail, and also those patients who have severe bronchial disease, particularly those with extreme degrees of stenosis.

We have now done pulmonary resection in twenty-one cases of pulmonary tuberculosis. Twelve of these have been total pneumonectomies. Nine of them have been either partial lobectomies, bilobectomies, or a lobectomy and a half. Six patients had extreme bronchial stenosis, seven had had previous thoracoplasty or (one) extraperitosteal collapse.

In these cases of lung resection after thoracoplasty, in spite of extreme care, three cavities were ruptured during the procedure. Each patient developed a tuberculous empyema, simple, but nevertheless empyema. We do not, therefore, believe one should routinely plan to do thoracoplasty first and then lobectomy later if necessary. We think one should endeavor to choose the proper procedure first and do it first.

Case 1 (Slide 1). This is a case of a 26-year-old girl who had had tuberculosis for several years and had previously had pneumothorax on the left side; the large apical cavity is seen on the right.

(Slide 2.) This is subsequent to lobectomy, two days postoperative. The right lung is nearly expanded.

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*See page 1 for article by Dolley.
†See page 3 for article by Janes.
‡See page 20 for article by Maier and Klopstock.

(Slide 3.) This is how she looked at the time she left the hospital. The remainder of the right lung fills the entire hemithorax. The lesion on the other side remains as it had been.

Case 2 (Slide 4). Here is a 31-year-old woman who had several months of 95 per cent pneumothorax on the right and this extensive underlying cavitation is seen. The other lung remains clear.

(Slide 5.) This is subsequent to pneumonectomy which caused her no trouble. You note the other side stays good—as good as preoperatively.

(Slide 6.) This is several months later. The right chest is completely filled with sterile fluid.

Case 3 (Slide 7). Here is a case we considered comparable in the extent of disease. Pneumothorax had been tried unsatisfactorily and pneumonolysis could not be done. The right side, as will be noted, is clear. Because of technical difficulties the bronchus was not clamped early during the pneumonectomy. It was difficult to get to it because this large cavity in the upper lobe was adherent to the chest wall.

(Slide 8.) This is the postoperative film showing the contralateral spread which occurred from the operation and, we think, because we did not clamp the bronchus early. In five cases in this series we failed to do that. Four of the patients developed contralateral spread and two died four months later.

(Slide 9.) This is a picture showing increase in the primary spread. Her sputum is positive. The left thorax is completely filled with sterile fluid.

We have had in these twenty-one cases, six deaths. One was purely anesthetic. Three deaths were due to postoperative spread, although only two of them were immediate postoperative spreads. One followed the opening of a bronchial fistula three weeks later. Two deaths were due to pyogenic infection of the pleura.

DR. E. J. OBRIEN, Detroit, Mich.—I think these papers and all the reports on lobectomy and pneumonectomy have shown us that it is probably less hazardous a procedure than we formerly thought and, therefore, in those patients in whom the more simple procedures of collapse therapy cannot be applied, we can, with less concern, go ahead with them.

I agree with Dr. Chamberlain, however, that there are a number of factors involved. I was not very impressed with the results in this or any other series of pulmonary resection for tuberculosis that I have seen. There have been a lot of spreads, empyemas, and persistent positive sputums. The results are not as impressive as those from thoracoplasty and other forms of collapse. Much more study is required before the indications for resection are made clear.

The indication especially startling to me was the one of Dr. Maier's. He did an upper lobe lobectomy on one side because he contemplated collapsing the opposite lung later. I would attempt to control the disease in one lung first by collapse measures and then try the same on the opposite side before considering lung resection, which could cause only added burden, as Dr. Chamberlain showed, to both lungs.

Tuberculosis is an unpredictable disease. I am afraid there are going to be a lot of terrifying experiences for both the patient and the doctor in years to come if we promiscuously deprive the patient of too much good lung tissue. I think we should try to retain as much normal parenchyma as we can. If collapse therapy methods are not efficacious we can always resort to resection later. A stricture of the bronchus in itself is not necessarily a contraindication to thoracoplasty nor an indication for lung resection. I have seen a large number of patients in whom the stricture has been dilated between the stages of thoracoplasty, and the results have been surprisingly good if the stricture is not too extensive. With the great improvement in technique acquired during the past few years, the immediate hazards of the

operation have been greatly reduced, but I do not feel that the results shown so far prove that collapse measures should be replaced, except in a very limited number of patients, with lung resection.

DR. JOHN ALEXANDER, Ann Arbor, Mich.—Dr. Dolley's evaluation of pulmonary resection for tuberculosis seems to me sound and wise. We should be on guard against overenthusiasm for resection, just as we should have been on guard against overenthusiasm for the Semb apicolysis, extrapleural pneumothorax, and Monaldi cavity drainage. I believe resection and other procedures just mentioned have a definite place in the treatment of tuberculosis but that this place should be limited to relatively few patients for whom less risky operations, which produce better results, are definitely not suitable. In our clinic we use all these operations under these conditions. We shall, however, learn much from the experience of those who are using pulmonary resection on a pioneering or experimental basis.

Ideally, lobectomy or pneumonectomy would remove all the pulmonary tuberculous lesions, thereby eliminating the disease from the patient. Unfortunately, in various series a disappointingly large proportion of the patients in whom resection was done continue to have tubercle bacilli in their sputum, the organisms coming from tuberculous ulcers in or near the bronchial stump, or from spreads to, or reactivations of, tuberculous lesions in remaining pulmonary parenchyma. If a spread occurs in the remaining lung after a total pneumonectomy, and if this does not clear rapidly, the ultimate prognosis is obviously poor.

Dr. Richard H. Sweet has kindly given me the figures from the Massachusetts General Hospital: In thirty-five patients there have been nineteen pneumonectomies and sixteen lobectomies. Twenty of these patients are now in good health from a few months to five years after operation. Four have been operated on too recently for a proper evaluation of the result. There were four deaths directly connected with operation and one later death resulting from a postoperative spread of the tuberculosis. Six of the thirty-five patients are living with active tuberculous lesions.

Dr. Norman Wilson will present to us a summary of his and Dr. Overholt's results in their last sixty cases, which will be presented in greater detail next week at the meeting of the American Trudeau Society. I understand that they have used total pneumonectomy or lobectomy in more than 100 patients and that the over-all early and late mortality in their first 61 patients was 22.9 per cent, and that the sputum studies in 34 of the living patients were as follows: negative to more sensitive types of examination than plain smears, 13; tested by smear only and negative, 8; positive, 13.

There can be no doubt that Dr. Maier and Dr. Sweet, Dr. Churchill and Dr. Klopstock (representing the Massachusetts General Hospital), and Dr. Overholt and Dr. Wilson have saved a good many lives with pneumonectomy and lobectomy that could not have been saved by any other treatment. Except in Dr. Maier's series of sixteen cases, the mortality rate is several times higher than that of thoracoplasty and, therefore, I believe that when there is a choice betwen thoracoplasty and resection in individual cases, thoracoplasty should be chosen. Dr. Overholt has made the statement elsewhere that resection must not be considered as a competitive operation with respect to thoracoplasty. If it is true, however, that Dr. Overholt and Dr. Wilson have carried out pneumonectomy or lobectomy upon more than 100 patients within a period of only a few years, I submit that they must have used these operations for a good many patients for whom most of us would consider thoracoplasty suitable.

DR. JOHN C. JONES, Los Angeles, Calif.—At the expense of being accused of dragging things in by the coattails, I would like to discuss a type of bronchial closure because I think the bronchial closure is a prime consideration in any pneumonectomy or lobectomy, whether it be for tuberculosis or new growth or any other

disease. There are those who say that if the bronchial stump is buried, it doesn't make much difference how the bronchus is closed or what is used to close it. I don't agree with that. I think the bronchial stump closure must be meticulous if the lobe or the lung is removed.

(Slide 1.) Here is the drawing of the type of closure I have been using; a 35 gauge stainless steel wire is incorporated in an atraumatic needle, and the suture is passed proximal to the clamp after the bronchus has been amputated. Eight of these are usually needed in a primary main stem bronchus. After the sutures are all passed over the clamp, then they are drawn up into the wound as the clamp is withdrawn and that holds the bronchus closed.

Then the sutures are tied over the end of the bronchus. I think this is a very simple way of closing the bronchus. It is practical. The bronchus is closed during the repair, and I make the point not to strip the bronchus above the site of the amputation so the bronchial artery will not be injured. I do not use any mattress sutures proximal to the cut end of the bronchus. I have seen no complications from the use of the clamp, and I would much rather have a bronchus clamped during the repair than an open, blowing bronchus.

Furthermore, if in the case of the malignancy a high amputation is needed, this type of closure can be used where the bronchus is cut off at the level of the carina. One utilizes a nonabsorbable material that actually creates a good deal less tissue reaction in a potentially infected stump, and I think that ulceration is far less likely to occur around the sutures of this type than if silk is employed. It makes a small hole of entrance and it maintains a good blood supply to the end of the bronchus; this I know because every time I take the clamp off, the bronchial artery bleeds, and we allow it to bleed until the sutures are all tied, then a fine suture of silk is taken in the bronchial artery at the end of the bronchus.

We always bury the stump with pleura or whatever material we can find. I think this is very important, too, but I am not willing to concede yet that any type of bronchial closure is adequate if it is buried with pleura.

DR. NORMAN J. WILSON, Boston, Mass.—It happens that one of the men from Dr. Overholt's clinic is here, and it has been a privilege to work with him. I shall present figures on sixty of the ninety-seven resections performed by Dr. Overholt as I have seen them myself. I have studied each of these resected specimens. In the vast majority of instances, we have tried to use resection in cases in which we anticipated from previous experience that a long-term bad result might be caused by collapse therapy. Of these sixty resections, one patient had two lobectomies.

(Slide 1.) Thirteen of the sixty patients were classified as desperate risks. We have used this "desperate risk" classification in spite of the fact that we know we will be asked about it. These cases meet in every respect the classification of the desperate-risk case by Dr. Alexander in his textbook. This is a very important point when any group of patients is being considered. These thirteen patients were really desperate risks. All of them were going downhill with the brakes off.

The incidence of tuberculous bronchitis in the entire group which could be diagnosed by bronchoscopy was 31.7 per cent. Ninety per cent of all the patients had positive sputum at the time of resection.

(Slide 2.) This shows the increased utilization of resection in the sanatoriums of New England in which we work. Since these patients were referred by physicians who were interested in their getting well, it speaks for the fact that we are tackling tough problems and getting results.

(Slide 3.) This represents the type of resection done. As can be seen, there were six left upper lobectomies. All these operations were done with individual ligation technique.

(Slide 4.) In 1942, Thornton and Adams collected seventy-five cases of resection from the literature. There was a high incidence of persistent fistula, empyema,

and contralateral spread as shown by this slide. As you notice, in Dr. Overholt's series in the thirty-six pneumonectomies, the incidence of persistent fistula was 2.7 per cent. Naturally, the case had an associated tuberculous empyema. The incidence of contralateral spread was 11.1 per cent and of nontuberculous (*Staphylococcus aureus*) empyema 5.5 per cent. Contralateral spread remains the greatest threat. To compat this, we make ligation of the bronchus the first step in the resection whenever possible and it is possible in the vast majority of pneumonectomies. We also are now devising an intrabronchial anesthesia tube with a septum down the middle and a balloon around the stem in the left bronchus so that each lung will be exteriorized for respiration and proper suction. We feel that this is going to be a big help in overcoming bronchial spillage.

(Slide 5). This slide gives mortality figures. These thirteen desperate-risk patients that I mentioned were of a type that I have never seen being operated upon by thoracoplasty. They were the ones who stayed in the medical division and died, where I have worked before, and I have worked in five thoracic clinics in the last eight years. The operative mortality in the reasonable-risk cases was 4.2 per cent; in the desperate risks, 38.5 per cent. Over one-half of these patients died of shock, embolism, and causes incident to the poor general condition of the patient and not related to the tuberculosis infection. If the breakdown into desperate and reasonable risks is not suitable, the total operative mortality is 11.6 per cent, and the total case mortality, to date 13.6 per cent.

I neglected to mention that these sixty patients were operated upon between January, 1942, and January, 1944. The earlier cases were left out because during this time the operative technique was not standardized. I think this is reasonable because I am sure that no one would want even thoracoplasties judged by 1930 results. The first case in which resection was done was in 1934 and the patient is still well and working, but we do not have data on the sputum examinations.

(Slide 6.) In the twenty-four lobectomies, there were no persistent fistulas, no empyema, and the incidence of contralateral spread was almost identical.

(Slide 7.) We have had a wonderful chance to study the surgical pathology of tuberculosis, not autopsy pathology. This slide presents a very interesting finding, because, as can be seen, the strip of bronchus immediately adjacent to the suture line was positive in 50 per cent by microscopic examination and the segment lower down in the main bronchus in 56 per cent. Dr. Alexander mentioned bronchial disease on the contralateral side where there is no parenchymal lesion. I understood him to say that; perhaps I misunderstood him. We have never seen, in our specimens, an involved bronchus that was not draining a parenchymal focus.

(Slide 8.) This slide outlines some of the reasons we feel that we have failed in some lobectomies. Results of the pneumonectomies have been much better, and we feel that any considerable amount of operable disease left behind is definitely a threat. On the right side, especially if a dorsal division cavity is present, extensive tuberculous bronchitis is almost always associated. For this reason, a middle and lower lobectomy is much better than just a lower lobectomy. This permits the bronchial suture line to be placed through an uninvolved portion of the intermediate bronchus.

Finally, I would like to read a concluding paragraph of our paper. "In our opinion, pulmonary resection will find its true place as a supplementary and not a competitive form of therapy to the already established methods of resection and collapse therapy. It will undoubtedly become an elective procedure in certain types of disease. Pulmonary resection should be used not as a last resort, but before extension of disease and complications have occurred." We feel that good results will come about when the patients are in good general condition.

DR. JOHN W. STRIEDER, Boston, Mass.—I am perfectly willing to confess that my ideas relative to the place of lobectomy and pneumonectomy in tuberculosis

are not exactly crystal clear. As a matter of fact, any discussion at this time regarding certain indications must be regarded as a purely philosophic one until sufficient time has elapsed in order that the results may be evaluated, possibly five years. I refer to those cases in which lobectomy is done as a definitive operation on patients who might be considered legitimate candidates for modern extrapleural thoracoplasty. It appears to me that even the most obdurate phthisiotherapists would now agree that there are certain well-defined indications for lobectomy in pulmonary tuberculosis. For me these include (1) so-called tuberculoma, (2) tuberculous bronchiectasis, (3) certain tension cavities, (4) stenotic lesions, and (5) residual cavities after thoracoplasty failure. So-called primary lobectomy performed in cases in which one might, until recently, have performed thoracoplasty without hesitation, appeals, as Dr. Chamberlain has mentioned, both to the surgeon and to the patient, and in my limited experience, which is now seven cases with one death, is worthy of further trial. For my part, I propose to continue to use it in selected cases. I do not believe lobectomy is the philosopher's stone in the treatment of pulmonary tuberculosis, but I do think that we have, in what has been said so far this afternoon, overlooked one fact which has been the will-o'-the-wisp pursued by those who have treated tuberculosis since the disease has been recognized, namely, that the total extirpation of the gross foci of the disease is a much to be desired end result.

Churchill and Klopstock have shown that this may be achieved as demonstrated by loss of sensitivity to tuberculin at a variable length of time postoperatively. This achievement may be repeated many times in selected cases, but the distribution of tuberculosis in the lungs being what it is, such achievements will, for the most part, be purely fortuitous. I think this is not the time to stand up and cheer and stop working, but I certainly think it is not the time to cry havoc and go home.

DR. DERYL HART, Durham, N. C.—My experience in pneumonectomies and lobectomies for tuberculosis has been largely restricted to cases of bronchial stenosis where resection is imperative. However, I have been impressed this afternoon by the number of infected wounds that have been reported. Of course none of these operations could be classed as "clean operations" since in all the bronchus had to be cut across. However, I believe from personal experience that the number of empyemas with secondary infection, and the infections which Dr. Alexander mentioned, might be reduced by the elimination of air contamination. A number of years ago we exposed ourselves to much criticism by publishing a 30 per cent infection rate in thoracoplasties. This percentage included all mild infections. We reduced that infection rate to three-quarters of 1 per cent by controlling the air contamination, and infections since that time have never been a serious problem with us. The North Carolina State Sanatorium had a 25 per cent infection rate which was stopped sharply by the institution of ultraviolet irradiation of the air. In the next series of approximately 100 consecutive thoracoplasties there was only one infection and that in a wound reopened for one of the subsequent stages.

I will show slides from five cases of pneumonectomy for tuberculosis, giving the temperature curves illustrating the very slight reaction where secondary air contaminants have been eliminated. All these patients except one child had been sick for from seven to ten years and had had various treatments.

The first patient's operation performed in 1941 required three hours, since the lung was very densely adherent. The maximum postoperative temperature reaction was less than 100° F. She had a temperature elevation reaching 102 and 103° F. before operation. It dropped to normal immediately after removal of the diseased lung and she has remained well since.

The operation on the second patient lasted three hours and fifteen minutes. The maximum postoperative temperature was 100.4° F., but only on two occasions, and

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the general level was not above that recorded preoperatively. She has been well since 1942.

The third patient, with a densely adherent lung, had an operation lasting something over four hours.

The lung was removed by going through large amounts of tuberculous tissue, much of the dissection being outside the parietal pleura. He developed a tuberculous empyema with a temperature elevation ranging between 100 and 102° F. However, the cavity remained free of secondary infection for approximately six to eight weeks. The tuberculous infection gradually dissected out and we did a secondary closure in an attempt to avoid such a complication. Following this the bronchus opened. This necessitated open drainage and a collapsing operation. The patient is now getting along quite well, but still has some drainage.

The fourth patient was a child 6 years of age admitted with a diagnosis of tracheobronchial tuberculosis, with bronchial stenosis of the right lower lobe bronchus. Lobectomy was performed. The postoperative temperature rose to a maximum of 102° F. but was down below 100° F. within forty-eight hours and remained down throughout the remainder of the hospital stay.

The fifth patient, having had a thoracoplasty for large cavitations which did not close, with a persistence of over one cupful of sputum a day, had the lung removed since adequate collapse of the cavities seemed impossible. The operation required four hours. The patient's postoperative temperature did not go above 99.5° F. and most of the time was near the 98.6° F. line. In the postoperative course she seemed to be getting along quite well, giving no cause for worry. She was seen at 4 A.M. on the sixth postoperative day and her condition semed to be satisfactory, "she was breathing easily as usual, pulse 120." At 4:15 A.M. she was found cold and clammy and five minutes later, when the intern arrived on the floor, she was pronounced dead. Death was thought to have been due to a pulmonary embolus.

As a further illustration of the low postoperative temperature reactions where air contaminants are eliminated, I want to mention a case of a lung abscess from which the bronchoscopist aspirated 1,200 c.c. of pus at one time. The lung was riddled with many abscesses and pneumonectomy required five hours operative time. The maximum postoperative temperature recorded was 99.5° F. Recovery was uneventful.

The great reduction in the postoperative systemic reactions brought about by eliminating much of the bacterial contamination from the air is probably equally as important as the reduction in the number of postoperative wound infections.

DR. LOUIS R. DAVIDSON, New York, N. Y.—We have performed ten pneumonectomies and three lobectomies for pulminary tuberculosis. Almost all of the pneumonectomies were performed in bad-risk cases. I do not mention these operations for any other purpose except to tell you that we have had experience in this particular field. However, one must be careful in evaluating results in pioneer work. Therefore, I call your attention to the fact that when Brauer and Friedreich first performed thoracoplasties their mortality rate was perfect—their first nine patients died.

I believe we can well say that excisional surgery in pulmonary tuberculosis is not impossible, yet we must recognize that an open mind should be kept and that, at the moment at least, every person suffering from pulmonary tuberculosis is not a candidate for excisional surgery.

DR. R. G. URQUHART, Uncas-On-Thames, Norwich, Conn.—If I am wrong I stand to be corrected. One of the previous speakers mentioned 100 lobectomies and pneumonectomies without a single infection. I certainly want to go up there and see how that is done. One of the bugaboos and one of the things I am most fearful of in regard to lobectomy or pneumonectomy is, of course, empyema, and it

seems almost astonishing to me that 100 of these cases could be done without one infection.

I think one thing we probably have lost some track of, which was demonstrated here today, is that it is possible technically to do lobectomy or pneumonectomy. That has been proved. Whether or not that is the proper treatment in so far as tuberculosis is concerned, I agree with the last speaker—let us keep an open mind. Don't let's go off the deep end.

DR. S. O. FREEDLANDER, Cleveland, Ohio.—The original patient for whom lobectomy for pulmonary tuberculosis was done, reported in 1934, is alive and in fairly good condition. Our subsequent experience with pulmonary resection has not been very extensive. We are convinced of the technical feasibility of the operation; however, we are still in doubt regarding the selection of cases. Two patients with tuberculous stricture of the bronchus with inactive disease, thus presenting rather ideal indications for pneumonectomy, had an uneventful postoperative course for three months and then suddenly developed widespread disease on the other side.

There is one type of pulmonary tuberculosis which we consider ideal for lobectomy. This is a case in which the tuberculosis of the bronchus comes extrinsically from a tuberculous node which invades the bronchial wall and causes stricture. Subsequently, these patients develop bronchiectasis and retention. We have had two such cases. This type of extrinsic tuberculous stricture of the bronchus has not been widely discussed and is probably more frequent than is recognized.

The papers and discussion of lobectomy and pneumonectomy in pulmonary tuberculosis given this afternoon will help to clarify greatly the problem regarding the place of pulmonary resection in this disease.

DR. FRANK S. DOLLEY, Los Angeles, Calif.—This has been a remarkably fine symposium on the subject of pulmonary resection. It seems to me that, after considering all criteria mentioned by the speakers, the probable results obtained, had other forms of treatment been tried, and the end result that followed pulmonary resection, the acid test should be: if we were in the situation of each particular patient would we choose this procedure for ourselves.

Dr. Alexander's attitude toward lobectomy and pneumonectomy in pulmonary tuberculosis I believe to be the correct one: a sharp word of warning frequently repeated during these next few months against too enthusiastic acceptance of immediate postoperative results. What disasters may occur months later, directly or indirectly, due to lung removal we can do little more than hazard a guess.

Dr. Strieder's criteria for pulmonary resection I think to be conservative and well advised. Lung resection is likely to be indicated:

(1) If the disease is largely bronchiectactic and the tuberculosis not particularly active

(2) Cavities at mediastinum, hilum, or lower lobe where prognosis for closure by other means is far from good

(3) Tension cavities under conditions already mentioned

(4) After thoracoplasty where clear evidence that cavity closure is not to occur except by extrapleural pack or external drainage, and then only after careful consideration of operative risks and probable comparative results

(5) Progressive stenosis of main or secondary bronchus

It is self-evident that none of these is a uniform indication for pulmonary resection yet it is a source of great comfort to know that such a recourse exists. In the meantime, during these developmental years, caution is the key word in the selection of cases.

DR. ROBERT M. JANES, Toronto, Canada.—It is impossible to comment upon the remarks of all the discussors of papers. I thank them all. The effect of overdistention of the remaining lung tissue has been one of our greatest fears. I think

it is not important except in so far as it might result in extension of the tuberculous process. Our experiences so far have been, on the whole, fortunate in that surprisingly few patients have had serious lighting up of pre-existing disease. Our experiences over many years with patients who have had pneumonectomy or lobectomy for other diseases would not lead us to believe that it is serious apart from this possible effect upon previously quiescent disease. It would obviously be attractive to avoid thoracoplasty if that were possible. From the patient's point of view an upper lobe lobectomy is attractive.

I can only thank Dr. Alexander for his remarks because I think that I agree with everything that he has said. I think I disagree with Dr. Bailey's choice of cases. My experience with operations for joint tuberculosis, which was considerable some years ago, led me to believe that it was dangerous to operate upon a patient with acute tuberculous disease. I think this probably applies to pulmonary tuberculosis. I would not have chosen, I think, any of the cases which you presented.

Dr. O'Brien, I feel certain, appreciates that we do not for a moment suggest that these procedures should replace thoracoplasty. Obviously each will have its place. Our experience with collapse therapy for stenosis of the bronchus, particularly in those patients who had secondary infection beyond the stenosis, has not been particularly happy. In relation to Dr. Hart's remarks, most of the infection is by the staphylococcus and recent results with penicillin in staphylococcus infection of the pleura would lead us to believe that when available it may be the answer.

I shall show four or five slides which will illustrate in a general way the type of case in which we have done lobectomy.

(Slide 1.) Here is an x-ray of a patient who had a pneumothorax with good collapse of the upper lobe, but the cavity remained open. That patient had a lobectomy and is now well, cough- and sputum-free.

(Slide 2.) Here is a young girl who had had a pneumothorax for more than one year and had left the sanatorium, but her sputum remained intermittently positive and planograph demonstrated cavitation in the collapsed lobe. There was a small lesion here on the opposite side. She is the patient whom I mentioned as having been kept in bed because of fear of this lesion. She has done well.

(Slide 3.) Here is a patient with a lesion in a very small collapsed lower lobe. No cavity could be demonstrated. Bronchoscopy showed that the sputum was coming from this collapsed lobe. I think she left the hospital on the fourteenth day.

(Slide 4.) Here is a cavity, in the lower lobe, uncontrolled by pneumothorax. The pneumothorax was allowed to absorb and a partial pneumonectomy was done.

(Slide 5.) Here is a slide of a patient with tuberculous bronchiectasis of the lower lobe; the lobe is obviously very small. The patient did well following lobectomy.

DR. HERBERT C. MAIER, New York, N. Y.—We have also been interested in the effect of lobectomy on lung function. From previous clinical experience and also rather extensive respiratory physiologic studies, including bronchospirometry, that have been carried on at Bellevue Hospital over a period under Dr. Richards' and Dr. Cournand's direction, we believe that the respiratory disturbances following lobectomy for bronchiectasis are usually relatively slight. However, as Dr. Chamberlain has mentioned, there may be a difference in the problem of upper as contrasted with lower lobe lobectomy. I feel that we do not have enough data on upper lobe lobectomies to offer conclusions at this time.

It should be pointed out that any study of respiratory function, done at a time when considerable pleuritic reaction remains from the operative procedure, may give a different result than studies made at a later date. This does not necessarily mean, however, that the pleuritic reaction will always subside so that the later result will necessarily be better than an earlier postoperative result.

I did not mean to infer that a cavity which was not closed by pneumothorax would not respond to thoracoplasty. I fully agree that many such cavities are closed by thoracoplasty. However, in a number of our apparently successful cases in this group the cavity was later reopened under thoracoplasty, so that it has been our impression that the late results of thoracoplasty in the pressure type of cavity are considerably less favorable than the early results.

In reference to the one case in which Dr. O'Brien wondered why we did an upper lobe lobectomy and then were planning perhaps to collapse the other side later, I tried to indicate that in that case the right upper lobe was an extremely shrunken, functionless mass of tissue, and the remainder of the right lung had already almost completely filled the hemithorax. Therefore, in that case the functional disturbance, aside from temporary pleuritic reaction, would be decidedly less after lobectomy than following thoracoplasty. In other words, the disturbance following thoracoplasty is influenced somewhat by the type of disease present. I might also say that the decrease in function following thoracoplasty is considerably greater when seven or eight ribs are removed as contrasted to the six-rib thoracoplasty to which Dr. Chamberlain referred.

MAJOR J. MAXWELL CHAMBERLAIN, Army of the United States.—I should like to express my appreciation to the discussors and especially to Dr. George Wright and Dr. Warriner Woodruff who very generously did the functional studies in these cases, and who helped me crystallize my own ideas about upper lobectomy in tuberculosis. They have taught me, and I have tried to demonstrate to you, the importance of reviewing the chest x-ray from the standpoint of physiology as well as the existing pathology. Some of us have focused our attention entirely upon the x-ray shadow without realizing that tremendous functional damage may be present in that area of the x-ray which looks normal.

The second point I should like to emphasize is the importance of bronchial peristalsis so beautifully demonstrated by Dr. Holinger's movie. Those of you who are bronchoscopists as well as thoracic surgeons have undoubtedly noticed the silence or immobility of the bronchial tree on the side of the resection, after removal of the upper lobe. Through overdistention of the remaining lobe the bronchus is lengthened and partially maintained in that state. This is also probably true of the thin-walled bronchiole not visible at bronchoscopy. I mention this point because we are so interested today in spreads, and it should be remembered that ciliary action and bronchial peristalsis are important mechanisms by which spreads are prevented.

PULMONARY RESECTION IN THE TREATMENT OF TUBERCULOSIS

Preliminary Report

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RESECTION of tuberculous tissue is now a procedure with such a margin of safety that it should be included with other possible methods when consideration is being given to a plan of treatment.

The extirpation of lung tissue involved by tuberculosis is not a new idea. In fact, in 1881 Block[1] made the first attempt to perform such an operation. However, most of the reports on pulmonary resection for tuberculosis have appeared during the past ten years. In 1935, Friedlander[5] reported a successful upper lobectomy. Since then several reports have appeared, notably those of Dolley and Jones,[3, 4] Thornton and Adams,[8] Samson,[7] and Churchill and Klopstock.[2] In the early part of the past decade, results were discouraging. The operative mortality was high and the incidence of serious complications, such as contralateral spread, empyema, and bronchial fistula, was prohibitively high. This led Thornton and Adams[8] in 1942 to conclude, after summarizing the literature, that "resection of lung tissue is very hazardous in the presence of a positive sputum." However, more recent experiences and reports have been much more encouraging.

The development of newer operative techniques, especially the individual ligation technique of treating the hilum and the pleural flap method of closing the bronchus, has made the operative procedure much safer and has greatly reduced complications. Rapid advances in anesthesiology have aided in carrying patients through operation safely. Bronchoscopy has revealed the presence of bronchial tuberculosis in many patients. This has helped to avoid many of the mistakes made in the earlier selection of cases, and to plan the proper operation and extent of resection.

The present report deals with sixty-three pulmonary resections performed upon sixty-one patients with pulmonary tuberculosis. These patients were all operated upon by one of us (R.H.O.) between 1934 and July, 1943. The entire series has been broken down into two large groups. The first group includes eighteen patients operated upon before Jan. 1, 1942. During this time, the criteria for the selection of patients, the operative technique, and the pre- and postoperative care were not as well standardized as they have been since that time. Many of these patients were operated upon not for the tuberculosis, but because of associated suppurative disease. The tourniquet technique was used in three cases. The pleural flap method of closing the bronchus was not

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used routinely. The second group comprises forty-five resections done since January, 1942. Individual ligation of the hilar structures and the pleural flap method of closing the bronchus were used routinely. We feel that the statistics in the second group really represent what pulmonary resection has to offer the patient with tuberculosis today.

These cases have been further subdivided into the desperate risk and the reasonable risk groups. The desperate risk patients were those accepted for operation more or less as a last resort. Many of them were those in whom collapse therapy had failed. In the remainder, collapse therapy was considered to be either contraindicated or inadvisable. It was the opinion of the clinicians taking care of these desperate risk patients that they possessed a fatal type of tuberculosis and resection offered them their only chance to get well. Any salvage in this group could be considered as pure gain.

GENERAL STATISTICS

Table I presents general statistics. There were sixty-three operations on sixty-one patients; two of these patients had a second lobectomy. There were thirty-five pneumonectomies, twelve on the right side and twenty-three on the left, and twenty-eight lobectomies. We should like to call attention to the six left upper lobe resections, all of which were performed with individual ligation technique without any unusual technical difficulties. This is not in keeping with the concept of Kent and Blades[6] who state in reference to the left upper lobe that, "except under unusually favorable circumstances, the individual ligation technique for resection of the left upper lobe will be hazardous or impossible." The age of the patients varied from 15 to 57 years. Fifty-three of the patients were between 20 and 40 years of age. Fifty-one of the sixty-one patients were women. This greater preponderance of women may be explained somewhat by the high incidence of endobronchial tuberculosis in this group. As is generally known from most reports, this complication is much more common in women. Twenty-three patients, or 37.7 per cent, had endobronchial tuberculosis. Fifty-five patients, or 90 per cent, had a positive sputum at the time of resection. The group of six patients who had negative sputa was made up of four in whom there was associated abscess or bronchiectasis, one with tuberculoma, and one with basal tuberculosis who had had pneumothorax for three and one-half years with intermittently positive sputum and frequent hemoptyses. The high incidence of positive sputum in this series of cases is noteworthy in view of the conclusions of Thornton and Adams[8] which were previously stated in the introduction to this paper concerning the hazard of resection in the presence of a positive sputum.

INCREASED APPLICATION OF PULMONARY RESECTION

Table II indicates a trend toward an increased application of pulmonary resection in the treatment of tuberculosis during the past ten years. As the safety of the operation has increased, the indications for

TABLE I

GENERAL STATISTICS

I	Number of patients		61
II	Number of operations		63
	Pneumonectomies	35	
	Right	12	
	Left	23	
	Lobectomies	28	
	Right upper	2	
	Right lower	5	
	Right upper and middle	3	
	Right lower and middle	3	
	Left upper	7	
	Left lower	7	
	Left lower and lingula	1	
III	Age of patients (15 to 57 years)		
	15 to 20	2	
	20 to 30	24	
	30 to 40	29	
	40 to 50	4	
	50 to 60	4	
IV	Sex		
	Male	10	
	Female	51	
V	Duration of disease		
	Under 6 months	8	
	6 months to 1 year	7	
	1 year to 2 years	8	
	2 years to 3 years	8	
	3 years to 4 years	7	
	4 years to 5 years	4	
	5 years to 6 years	7	
	6 years to 7 years	4	
	7 years to 8 years	0	
	8 years to 9 years	0	
	9 years to 10 years	1	
	10 years to 15 years	7	
VI	Incidence of endobronchial tuberculosis		
	23 cases	36.5%	
VII	Incidence of positive sputum		
	55 cases	90.1%	

TABLE II

DISTRIBUTION BY YEARS

YEAR	NUMBER
1934	1
1935	1
1936	0
1937	3
1938	1
1939	0
1940	3
1941	9
1942	22
1943	23
Total	63

resection, in our experience, have widened. Clinicians refer patients more frequently, and the vast majority of patients accept operation without hesitation. In fact, not infrequently patients request resection in preference to other possible forms of treatment.

INDICATIONS

The indications for resection as employed in this group are presented in Table III. There were ten cases in which associated suppurative disease was the indication. It was one of the most common indications in the earlier resections. Seven of the patients were operated on before January, 1942. In two of these an error in diagnosis was made. One had a small cavity in the left lower lobe and tuberculous bronchitis. The preoperative diagnosis was bronchiectasis. The other was one which had a large cavity in the superior division of the right lower lobe. This patient had a resection with a preoperative diagnosis of chronic lung abscess.

Eleven cases were thoracoplasty failures; four of the patients had had revisions which had failed to control the disease. In the remaining seven, resection was performed in preference to revisional thoracoplasty.

The most common indication for resection in this entire group has been the presence of extensive multilobar, predominantly unilateral tuberculosis. This was present in twenty-seven cases. Most of the patients had very extensive and active tuberculosis. They were all treated

TABLE III

INDICATIONS

		NUMBER OF CASES	
I	Associated suppurative disease		10
	A. Controlled tuberculosis with bronchiectasis in other lobes	4	
	B. Active tuberculosis with bronchiectasis in other lobes	3	
	C. Error in diagnosis	2	
	D. Extensive bronchiectasis, abscesses, and tuberculosis	1	
	Total	10	
II	Post-thoracoplasty, uncontrolled disease		11
	A. No endobronchial tuberculosis	8	
	B. With endobronchial tuberculosis	3	
	Total	11	
III	Extensive multilobar predominantly unilateral tuberculosis		27
	A. No endobronchial tuberculosis	11	
	B. With endobronchial tuberculosis	16	
	Total	27	
IV	Predominantly unilobar tuberculosis		5
	No endobronchial tuberculosis; resection elected in preference to thoracoplasty		
V	Basal (lower lobe) tuberculosis		7
	No endobronchial tuberculosis		
VI	Recurrent hemorrhages following thoracoplasty		1
VII	Tuberculoma		1
VIII	Active tuberculosis, bronchiectasis, post cavernostomy		1

by pneumonectomy. In our opinion, extensive thoracoplasty as an alternative form of treatment could have been considered a possibility in only five of them. In all others, thoracoplasty was either contraindicated or it was anticipated that thoracoplasty would fail to control the disease. Sixteen of these patients had endobronchial tuberculosis.

The indication in five cases was predominantly unilobar tuberculosis. The disease was located in the upper lobes. Lobectomy was performed in four patients. The fifth was treated by pneumonectomy because extensive involvement of the superior division of the lower lobe was discovered at the time of operation. In all five, resection was definitely elected in preference to thoracoplasty. They represent, in our opinion, the only truly elective resections in this entire series.

Basal tuberculosis was the indication in seven patients. Resection was carried out as a primary form of treatment in two, both of which had extensive involvement of the lower lobe. One had failed to respond to pneumothorax, another to pneumothorax plus phrenic, and a third had failed to respond to phrenic. The remaining patient had had pneumothorax for three and one-half years, and during this time had intermittently positive sputum and frequent hemoptyses. The lower lobe was quite small and opaque. Resection was performed because of the persistent symptoms and the recurring positive sputum.

Recurrent hemorrhage was the indication in one case. This patient previously had a thoracoplasty. Sputum was converted but she was totally incapacitated by frequent gross pulmonary hemorrhages. At the time of operation, the vital capacity was 900 c.c. and the patient was considered to be a desperate operative risk. The postoperative course was uneventful, and she is asymptomatic and completely well today.

Tuberculoma was the indication in one case. This patient had a tumor in the right upper lobe which had slowly progressed in size for two years. She was diabetic. Resection was performed successfully.

The remaining case was a very desperate risk. The patient had been ill for ten years and previously had pneumothorax and empyema on the contralateral side. Therapy on the operated side had consisted of pneumothorax, plombage, thoracoplasty, revision thoracoplasty, and cavernostomy. Operation in this case was truly a last resort procedure.

COMPLICATIONS

In 1942 Thornton and Adams[8] reviewed the entire literature on pulmonary resection in tuberculous patients. They collected records in twenty-nine pneumonectomies and forty-six lobectomies. Column one of Table IV gives the incidence of the most common complications in this collected series. These were persistent fistula, contralateral spread, and empyema. Column two of Table IV represents the results in our entire series of sixty-three patients. Column three represents the results in the resections performed between January, 1942, and July, 1943. All of the last forty-five patients were operated on with modern technique. This table is presented, not as a condemnation or criticism of the earlier

TABLE IV

MOST COMMON COMPLICATIONS

	THORNTON AND ADAMS COLLECTED SERIES OF CASES		63 RESECTIONS (OVERHOLT) 1934 TO JULY 1, 1943		45 RESECTIONS (OVERHOLT) JANUARY, 1942, TO JULY 1, 1943	
	NUMBER OF CASES	PER CENT	NUMBER OF CASES	PER CENT	NUMBER OF CASES	PER CENT
Pneumonectomy	29		35		25	
Persistent fistula		34		2.9		4
Contralateral spread		24		11.4		8
Empyema without fistula		17		8.5		8
Lobectomy	46		28		20	
Persistent fistula		39		14.3		0
Contralateral spread		25		14.3		15
Empyema without fistula		25		7.1		0

workers in the field, but to show the progress which has been made in the past decade. An analysis of this table demonstrates several significant facts: (1) Two of the complications, namely, persistent fistula and tuberculous empyema, were almost eliminated in the patients operated on with modern technique. Two cases of empyema without fistula occurred in this group, both of which were due to staphylococcus aureus and neither of which was complicated by tuberculous infection. There was only one fistula. This became manifest nine months following resection. This would indicate that the high incidence of these complications in the past has been due, not to the tuberculous infection per se, but to improper operative technique. (2) Although the incidence of contralateral spread has been reduced, it is still a very great threat. This complication is due, we feel, to bronchial flooding during the operative procedure and is the direct result of the tuberculous infection itself.

All complications are summarized in Table V. It has been divided into two groups: first, the complications related to the tuberculous infection, and second, those related to the surgical problem of pulmonary resection and associated diseases. That section on the complications related to tuberculous infection has been divided into two groups according to the operative technique applied. January, 1942, was used as a dividing line here because since that time all patients have received the benefit of the modern operation. As the table shows, there were no wound infections of any kind in the entire series. Empyema was a frequent complication in the earlier group but in the modern group only three patients, or 6.6 per cent, have had empyema. Two of these were caused by the *Staphylococcus aureus* and there was no evidence of tuberculous infection in either. The third patient just recently developed a fistula and empyema, nine months after operation. Concentrated smear of the empyema fluid is positive for tubercle bacilli. In the modern group, there has been one permanent fistula and one temporary fistula. This last case was very interesting in that the fistula was closed several weeks following pneumonectomy with a mus-

TABLE V (PART I)

COMPLICATIONS

I Complications Related to Tuberculous Infection

		PRIOR TO JANUARY, 1942 (18 RESECTIONS)		SINCE JANUARY, 1942 (45 RESECTIONS)	
		NUMBER OF CASES	PER CENT	NUMBER OF CASES	PER CENT
I	Wound infection	0	0	0	0
II	Empyema	7	38.8	3	6.6
	Without fistula	1		2 (both non-tuberculous)	
	With permanent fistula	4		1 (tuberculous)	
	With temporary fistula	2		0	
III	Temporary fistula	2	11.1	1	2.2
				Closed with muscle transplant; no empyema	
IV	Permanent fistula	5	27.7	1	2.2
V	Contralateral spread	3	16.6	5	11.1
VI	Contralateral exacerbation	0	0	1	2.2
VII	Contralateral lesion developing late	2	12.2	2	4.4
		1 (6 mo. P.O.)		1 (8 mo. P.O.)	
		1 (6 yr. P.O.)		1 (18 mo. P.O.)	
VIII	Ipsilateral spread	0	0	2	4.4
				1 (P.O. period)	
				1 (8 mo. P.O.)	
IX	Ipsilateral exacerbation	1	5.5	0	0
X	Ulceration in the stump of the bronchus	1	5.5	5	11.1
XI	Tuberculosis of the chest wall	0	0	3	6.6
XII	Contralateral pleurisy with effusion	1	5.5	1	2.2

TABLE V (PART II)

COMPLICATIONS

II Complications Related to Surgical Problem of Pulmonary Resection and Associated Diseases (63 Cases)

Circulatory failure	1
Paroxysmal heart action with sudden death	1
Pulmonary insufficiency	2
Diabetic coma	1
Embolism	1

cle transplant. A thoracoplasty was then performed. The patient did not develop an empyema; the wound healed by primary intention, and he is asymptomatic, negative, and well at the present time.

Contralateral spread has occurred in 11.1 per cent of the modern group. As stated before, this is due to bronchial spillage at the time of operation and today represents one of the greatest threats to the patient coming to resection for tuberculosis. An attempt is being made to overcome this complication by more vigilance in regard to the removal of bronchial secretions during the course of the operative procedure and by preliminary ligation of the bronchus as the first step in the dissection whenever it is technically possible.

In none of the earlier cases, and only one in the modern series did contralateral exacerbation develop. Four patients in the entire series developed contralateral lesions several months following operation. Two of these patients have died as the result of contralateral tuberculosis. One has progressive disease, and the other now has a pneumothorax to control the lesion. At the present time, she is asymptomatic, has a negative sputum, and is well.

Spread to the remaining lobes on the same side has occurred in two lower lobectomies. One occurred in the early postoperative period and the other developed a lesion in the upper lobe eight months following operation. Both of these patients had tuberculosis in the bronchial stump. This was diagnosed by bronchoscopic examination in one, and by pathologic study in the other.

Ulceration of the bronchial stump is a complication that occurs more frequently than is generally suspected. It can be diagnosed only by routine bronchoscopic examination following operation. Many patients operated on prior to 1942 were not studied bronchoscopically after operation, so that the incidence in this group was not determined. However, in the modern group of forty-five resections, thirty-three have had postoperative bronchoscopic examinations, and in five of these ulceration was found in the stump. This gives an incidence of 15.1 per cent for the patients who were bronchoscoped. This complication may occur early or late in the postoperative course. In one case, a lesion was found ten months following pneumonectomy, and then the only indication for bronchoscopy was a positive sputum by guinea pig inoculation. The patient was clinically well. Because of the difficulty in making a clinical diagnosis in these cases, we now advocate routine postoperative bronchoscopy six weeks following resection, and a repetition of bronchoscopy again in about six months. Bronchoscopic examination may be indicated more frequently when the sputum is found to be positive. Infection of the bronchial stump must be considered as a possible source of infection in the cases which develop late spreads. These ulcers have responded very well to treatment with 30 per cent silver nitrate. Of the six patients who have come to treatment, four are entirely well with no evidence of active ulceration in the stumps at the present time. Two of these patients are found negative on all tests, including guinea pig inoculations; two of them are found positive on guinea pig inoculations; one is still found positive on direct smear but she has been treated irregularly and has not returned for regular bronchoscopic therapy. The remaining patient has been treated by further resection, and at the present time is clinically well. The ulcers in the bronchial stumps occur at the site of the mattress sutures. For this reason, we have recently, when technically feasible, limited or omitted the mattress sutures and have closed the bronchus with end sutures. This permits a shorter stump and does away with the serrations caused by the mattress sutures. So far, none of these have developed ulceration. It is too early to determine just how effective this

change in technique will be in overcoming this complication. It is also too early to state whether this type of bronchial closure will be as effective in the prevention of postoperative fistula as was obtained with reinforcing mattress sutures.

As indicated in Chart I, we have considered three patients to have tuberculosis of the chest wall. These patients were very interesting in that following resection their wounds healed by primary intention without any evidence of the underlying pathology. All three had been treated by pneumonectomy. When they returned for thoracoplasty, and after the incision was made, granulation tissue was found in the chest wall. Sections were taken for examination, and all of them showed pathology consistent with tuberculosis. Nevertheless, rib resection was performed and the operation was completed in each case. All three wounds healed by primary intention and without induration or later evidence of infection. All three of these patients are well today, have no evidence of empyema, and have negative sputa.

Contralateral pleurisy with effusion has developed in two cases; one patient, in fact, had pleurisy with effusion twice. The fluid in this case was positive. The fluid in the other case was negative by guinea pig inoculation. Neither patient has developed an underlying parenchymal lesion, and both are at home leading normal lives and are well.

The second section of the table dealing with complications (Part II, Table V) lists those related to the surgical problem of pulmonary resection and associated diseases. They resulted in the death of the patient in each instance. These particular deaths, in our opinion, had nothing to do with the tuberculous infection itself, but were related to factors common to the problem of resection. The table is rather self-explanatory, but two cases bear comment: One patient was a diabetic who on the fourth day became comatose. At that time, the CO_2 combining power of the blood was nineteen volumes per cent. The pathologist's impression at autopsy was that the patient had died of diabetic coma. The other patient died of embolism on the fifteenth day; death was sudden and unexpected. Her postoperative course had been entirely uneventful.

MORTALITY

Tables VI through IX deal with the operative mortality. Table VI presents the mortality statistics for the entire series of sixty-three resections. The cases have been divided, as previously described, into reasonable and desperate risks. The total operative mortality for this group is 15.8 per cent and the total case mortality, 24.6 per cent. The operative mortality for the reasonable risks and the desperate risks was 6.3 and 43.7 per cent, respectively. There were five late deaths in this group so that the total case mortality for reasonable risks was 13.3 per cent and for desperate risks, 56.2 per cent.

Table VII presents the mortality statistics for forty-five successive resections done with modern technique since January, 1942. Here there

NAME	AGE	SEX	CASE NO.	PREOP. CLASSIF.	DATE OF OPERATION	INDICATION (FROM TABLE III)	ENDOBRONC. T.B.	SPUTUM	DURATION OF DISEASE
L. W.	35	F	D. 66613	R.R.	4/24/34	I B	+	+	15 yr.
C. C.	28	F	–	D.R.	2/23/35	I D	+	+	14 mo.
H. H.	36	M	D. 69104	R.R.	2/ 6/34	I B	+	+	4 yr.
L. C.	22	F	D. 79180	R.R.	2/21/37	I A	?	0	5 yr.
E. B.	32	F	316	R.R.	3/ ?/37	I A	0	0	?
J. M.	38	M	241	R.R.	9/15/38	I A	+	0	4¾ yr.
C. B.	37	M	248	D.R.	3/27/38	VIII	?	+	10 yr.
E. B.	35	F	316	D.R.	3/ 2/40	II A	?	+	3 yr. +
V. D.	28	F	1285	D.R.	12/10/40	III B	+	+	5 yr.
L. M.	57	F	1270	D.R.	2/ 6/41	III B	+	+	2 yr.
A. G.	41	F	1330	R.R.	3/25/41	III B	+	+	13 mo.
M. F.	16	F	1312	R.R.	3/29/41	I C	0	+	8 mo.
R. Y.	28	F	773	R.R.	7/ 8/41	II A	0	+	6⅔ yr.
R. F.	37	F	63	R.R.	7/14/41	II B	+	+	5½ yr.
N. S.	34	F	1604	R.R.	9/11/41	III B	+	+	10 yr.
B. L.	33	F	958	D.R.	9/26/41	III B	+	+	10 yr.
E. F.	27	F	1279	R.R.	11/24/41	III A	0	+	3 mo.
V. N.	30	F	552	D.R.	12/30/41	II B	+	+	3 yr.

PREVIOUS THERAPY		OPERATION PERFORMED	COMPLICATIONS		P.O. HOSP. DAYS	SPUTUM AT PRESENT	PRESENT CLINICAL STATUS
CONTRA LUNG	IPSA LUNG		P.O.	LATE			
0	Phrenic	L.L.L.	0	0	28	?	Well
0	0	Lt. pnectomy	Empyema	Phlebitis Pneumonia Uremia	–	–	Died 6 mo. P.O.
0	Thoro	L.L.L. & lingula	Temporary fistula Empyema	0	23	0	Well
0	Pnthx Phrenic Thoro	L.L.L.	Temporary fistula Empyema	Contralat. disease developed 5 yr. later	30	–	Died 6¾ yr. later of contralat. T.b.
0	0	Rt. M. & L.	Permanent fistula Empyema	Exacerbation of T.b. in R.U.L.	?	+	Had resection of R.U.L. later
0	Phrenic Thoro	Lt. pnectomy	0	0	24	Neg.	Well
Pnthx with empyema	Pnthx Plombage Thoro 2 revisions Covernostomy	Rt. U. & M.	Contralat. spread Permanent fistula Empyema	–	–	–	Died on 31st P.O. day of infection and pulmonary insufficiency
0	Rt. M. & L. Thoro	R.U.L.	Permanent fistula Empyema	–	36	Neg.	Poor pulmonary insufficiency
0	Phrenic	Rt. pnectomy	0	0	21	–	Died suddenly on street in July, 1942
0	0	Rt. M. & L.	Fistula Empyema C.N.S. Symptoms	–	–	–	Died on 32nd P.O. day of empyema and ? C.N.S. accident
0	Pnthx	Lt. pnectomy	0	0	23	Neg.	Well
0	0	L.L.L.	0	Contralat. lesion developed Sept., '41	27	Neg.	Now has rt. pnthx., asymptomatic and well
0	Phrenic Thoro Revision	Rt. pnectomy	Diabetic coma	–	–	–	Died on 3rd P.O. day of diabetic coma
0	Pnthx Thoro	Lt. pnectomy	0	Contralat. pleurisy with effusion	29	Neg.	Well
0	Pnthx Phrenic	Rt. pnectomy	Permanent fistula Empyema Contralat. spread	0	24	–	Died suddenly on 3rd day after plastic closure of bronchus
0	0	Lt. pnectomy	Contralat. spread	–	–	–	Died on 4th P.O. day of contralat. T.b. pneumonia
0	Pnthx Pnlysis	Lt. pnectomy	0	Stump ulceration	16	Neg.	Well
0	Pnthx Thoro Revision Phrenic	Rt. pnectomy	Pulmonary insufficiency	–	–	–	Died on 4th P.O. day of pulmonary insufficiency

NAME	AGE	SEX	CASE NO.	PREOP. CLASSIF.	DATE OF OPERATION	INDICATION (FROM TABLE III)	ENDOBRONC. T.B.	SPUTUM	DURATION OF DISEASE
M. R.	40	F	1785	R.R.	1/ 6/42	I A	?	0	10 yr.
E. M.	36	F	1907	R.R.	1/28/42	I B	?	+	7 mo.
A. R.	32	F	1675	R.R.	2/19/42	III B	+	+	6 yr.
E. A.	34	F	1172	R.R.	4/ 9/42	III B	+	+	2 yr.
R. B.	52	F	226	D.R.	4/27/42	VI	0	0	4½ yr.
M. S.	26	F	1634	R.R.	5/14/42	V	0	+	2 mo.
D. B.	26	F	1900	R.R.	5/15/42	V	0	+	3 mo.
J. G.	28	F	1187	R.R.	6/18/42	V	0	+	2½ yr.
M. B.	28	F	1755	R.R.	6/29/42	IV	0	+	2½ yr.
S. B.	15	F	1966	R.R.	7/17/42	III A	0	+	10 mo.
P. H.	29	F	2094	R.R.	8/12/42	III B	+	+	8 mo.
M. G.	29	F	1894	R.R.	8/25/42	V	0	+	17 mo.
J. Y.	39	F	2154	R.R.	9/18/42	III B	+	0	3 yr.
E. B.	35	F	2200	R.R.	10/ 9/42	I C	0	+	3 mo.
M. S.	41	F	2194	R.R.	10/12/42	VII	0	0	2 yr.
E. C.	25	F	2226	R.R.	10/23/42	V	0	+	3 mo.
A. S.	30	F	889	D.R.	10/27/42	III A	0	+	6½ yr.
M. C.	34	F	1999	R.R.	10/29/42	II A	0	+	3½ yr.
E. A.	33	F	1551	R.R.	10/30/42	III A	0	+	3 yr.
C. B.	22	M	1878	D.R.	12/ 1/42	III A	0	+	1½ yr.
J. T.	34	M	2269	R.R.	12/11/42	III B	+	+	7 wk.
T. B.	24	F	1903	R.R.	12/31/42	II A	0	+	22 mo.

I—CONT'D

PREVIOUS THERAPY		OPERATION PERFORMED	COMPLICATIONS		P.O. HOSP. DAYS	SPUTUM AT PRESENT	PRESENT CLINICAL STATUS
CONTRA LUNG	IPSA LUNG		P.O.	LATE			
0	Pnthx Empyema Schede	Rt. M. & L.	0	0	30	Neg.	Well
0	0	L.L.L.	0	0	–	Neg.	Well
0	Pnthx	Lt. pnectomy	0	0	27	Neg.	Well
0	Phrenic	Rt. pnectomy	0	Stump ulceration	20	Neg.	Well
0	Thoro Phrenic	Lt. pnectomy	0	0	23	Neg.	Well
0	Phrenic	L.L.L.	0	0	18	Neg.	Well
0	Pnthx	R.L.L.	0	Stump ulceration Spread to right upper	14	+	Had R.U. and M. lobectomy in Jan., 1944
0	0	R.L.L.	Spread to Rt. M. & U. lobes	0	21	+	Had rt. U. and M. lobectomy on 4/13/43
0	Phrenic Pnthx	L.U.L.	0	0	20	Neg.	Well
0	Pnthx	Rt. pnectomy	0	Contralat. lesion 18 mo. later	18	–	Died Dec., 1943 of contralat. disease
0	0	Lt. pnectomy	0	Contralat. pleurisy with effusion	25	Neg.	Well
0	Phrenic	R.L.L.	0	0	18	+	Clinically well sputum +
0	Pnthx	Lt. pnectomy	0	Contralat. lesion appeared May, 1943	28	Neg.	Well
0	0	R.L.L.	0	0	27	+	Has residual disease in rt. U. and M. lobes; has had thoro.
0	0	R.U.L.	0	0	–	Neg.	Well
0	0	L.L.L.	Contralat. spread	0	25	Neg.	Well
0	Pnthx Pnlysis	Lt. pnectomy	Empyema (Staph. aureus)	0	26	Neg.	Well; empyema entirely closed with thoro.
0	Pnthx Thoro	Rt. U. & M.	0	0	23	+	Has residual cavity in superior division of lower lobe
0	0	Lt. pnectomy	0	0	16	Neg.	Well
0	Phrenic Pnthx	Rt. pnectomy	0	0	22	Neg.	Well
0	0	Rt. pnectomy	0	Stump ulceration	24	Neg.	Well
0	Pnthx Thoro	L.U.L.	Contralat. spread	–	–	–	Died on 5th P.O. day of contralat. pneumonia (? T.b.)

NAME	AGE	SEX	CASE NO.	PREOP. CLASSIF.	DATE OF OPERATION	INDICATION (FROM TABLE III)	ENDOBRONC. T.B.	SPUTUM	DURATION OF DISEASE
E. H.	38	M	2309	R.R.	1/12/43	III A	0	+	13 mo.
E. C.	53	M	2260	R.R.	1/14/43	III A	0	+	1 yr.
M. P.	20	F	1655	R.R.	2/12/43	IV	0	+	20 mo.
E. P.	39	F	830	R.R.	2/18/43	II A	0	+	5 yr.
P. G.	34	F	2384	R.R.	2/26/43	III A	0	+	9 mo.
I. M.	24	F	2421	R.R.	3/20/43	III A	0	+	7 mo.
J. C.	54	M	2385	D.R.	3/29/43	III B	+	+	4 yr.
S. A.	25	F	2422	D.R.	4/ 2/43	III A	0	+	5 mo.
J. G.	31	F	1187	D.R.	4/15/43	III A	0	+	3½ yr.
E. M.	44	F	2010	D.R.	4/16/43	II B	+	+	5 yr.
W. K.	22	M	2374	R.R.	4/22/43	IV	0	0	10 yr.
M. A.	34	F	1439	R.R.	4/26/43	V	0	0	3 yr.
I. H.	22	F	1982	R.R.	4/27/43	II A	0	+	5¾ yr.
M. M.	32	F	2402	D.R.	5/ 3/43	III B	+	+	2¼ yr.
C. P.	25	F	1470	R.R.	5/ 7/43	IV	0	+	5¼ yr.
M. D.	33	F	914	R.R.	5/20/43	V	0	+	6 yr.
M. C.	25	M	2052	R.R.	6/ 4/43	II A	0	+	2 yr.
A. C.	21	F	2502	R.R.	6/ 1/43	III B	+	+	7 mo.
M. K.	28	F	2513	R.R.	6/ 7/43	IV	0	+	2¼ yr.
L. W.	25	F	2565	D.R.	6/12/43	III B	+	+	6 mo.
G. T.	35	F	2032	R.R.	6/21/43	III B	+	+	3½ yr.
M. S.	34	F	2489	R.R.	6/15/43	II A	0	+	9 yr.
A. B.	39	F	2568	R.R.	7/ 1/43	III B	+	+	11 yr.

I—CONT'D

PREVIOUS THERAPY		OPERATION PERFORMED	COMPLICATIONS		P.O. HOSP. DAYS	SPUTUM AT PRESENT	PRESENT CLINICAL STATUS
CONTRA LUNG	IPSA LUNG		P.O.	LATE			
0	Pnthx	Lt. pnectomy	Contralat. spread T.b. of chest wall	0	22	Neg.	Well; spread entirely healed; incision healed by primary intention
0	0	Lt. pnectomy	0	0	21	Neg.	Well
0	Phrenic	L.U.L.	0	0	17	Neg.	Well
0	Phrenic Thoro Revision	Lt. pnectomy	0	0	18	+	Clinically well; slight cough and expectoration
0	0	Rt. pnectomy	0	0	14	Neg.	Well
0	Pnthx	Lt. pnectomy	T.b. of chest wall	0	23	Neg.	Well
0	0	Lt. pnectomy	Exacerbation of contralateral disease	–	32	–	Died on 53rd P.O. day of T.b. and pulm. insufficiency
0	0	Lt. pnectomy	Paroxysmal irregular heart action	–	–	–	Died on 1st P.O. day
0	R.L.L. Phrenic	Rt. U. & M.	Contralat. spread	0	24	+	Has progressive T.b.
0	Phrenic Thoro	Lt. pnectomy	0	Stump ulceration	37	+	Clinically well; slight cough and expectoration
Pnthx	0	L.U.L	Temporary fistula closed with muscle transpl.	0	21	Neg.	Well
0	Phrenic Pnthx	R.L.L.	0	0	17	Neg.	Well
0	Thoro	L.U.L.	0	0	16	+	Clinically well
Phrenic	Pnthx	Rt. pnectomy	Circulatory collapse	0	–	–	Died on 2nd P.O. day
0	Pnthx	R.U.L.	0	0	10	Neg.	Well
0	Phrenic	L.L.L.	0	0	12	+	Clinically well
0	Pnthx Thoro Revision	Lt. pnectomy	0	0	19	Neg.	Well
0	Pnthx	Lt. pnectomy	0	Developed fistula and mixed empyema Feb., '44	20	+	Has fistula and mixed T.b. empyema
0	0	Lt. pnectomy	T.b. of chest wall	0	16	+	Well
0	0	Rt. pnectomy	Stump ulceration Contralat. spread	0	16	Neg.	Well; stump healed with $AgNO_3$ treatment
0	Pnthx	Lt. pnectomy	Empyema (staph. aureus)	0	16	Neg.	Well
0	Phrenic Thoro	L.U.L.	0	0	0	Neg.	Well
0	Pnthx	Rt. pnectomy	Embolism	–	–	–	Sudden death on 15th P.O. day

TABLE VI

MORTALITY STATISTICS, ENTIRE SERIES
(61 CASES, 63 RESECTIONS)

Operative mortality (63 resections)	
Reasonable risks	6.3% (3 of 47)
Desperate risks	43.7% (7 of 16)
Total	15.8% (10 of 63)
Total case mortality (61 patients)	
Reasonable risks	13.3% (6 of 45)
Desperate risks	56.2% (9 of 16)
Total	24.6% (15 of 61)

Note: There were five late deaths in this group.

TABLE VII

MORTALITY STATISTICS, RESECTIONS SINCE JANUARY, 1942
(44 CASES, 45 RESECTIONS)

Operative mortality (45 resections)	
Reasonable risks	5.5% (2 of 36)
Desperate risks	33.3% (3 of 9)
Total	11.1% (5 of 45)
Total case mortality (44 patients)	
Reasonable risks	8.5% (3 of 35)
Desperate risks	33.3% (3 of 9)
Total	13.6% (6 of 44)

Note: There was one late death in this group.

TABLE VIII

ANALYSIS OF POSTOPERATIVE DEATHS

NO.	NAME	AGE	OPERATION	PREOP. CLASSIFICATION		DURATION OF ILLNESS	T.B. BRONCHITIS	P.O. DAY OF DEATH	CAUSE OF DEATH
				DESPERATE RISK	REASONABLE RISK				
1	Mr. C. B.	37	Rt. U. and M. lobectomy	Yes		10 yr.	?	31	Contralateral extension; pulmonary insufficiency
2	Miss B. L.	38	Lt. pn'ectomy	Yes		10 yr.	Yes	4	Contralateral tuberculous pneumonia
3	Miss V. N.	30	Rt. pn'ectomy	Yes		3 yr.	Yes	4	Pulmonary insufficiency
4	Miss R. Y.	28	Rt. pn'ectomy		Yes	6⅔ yr.	0	4	Diabetic coma
5	Miss L. M.	57	Rt. M. and L. lobectomy	Yes		2 yr.	Yes	32	Fistula, empyema, C.N.S. symptoms
6	Miss T. B.	24	Lt. upper lobectomy		Yes	22 mo.	0	5	Contralateral tuberculous pneumonia
7	Miss S. A.	25	Lt. pn'ectomy	Yes		5 mo.	0	1	Paroxysmal irregular heart action with sudden death
8	Mrs. M. M.	32	Rt. pn'ectomy	Yes		2¼ yr.	Yes	2	Circulatory failure
9	Mr. J. C.	54	Lt. pn'ectomy	Yes		4 yr.	Yes	53	Contralateral exacerbation; pulmonary insuff.
10	Mrs. A. B.	39	Rt. pn'ectomy		Yes	11 yr.	Yes	15	Embolism

TABLE IX

ANALYSIS OF LATE DEATHS

NAME	AGE	OPERATION	PREOP. CLASSIFICATION		DURATION OF ILLNESS	T.B. BRONCHITIS	SURVIVAL PERIOD	CAUSE OF DEATH
			DESPERATE RISK	REASONABLE RISK				
Miss L. C.	22	Lt. lower lobectomy		Yes	5 yr.	?	6⅓ yr.	Contralateral tuberculosis
Miss C. C.	28	Lt. pn'ectomy	Yes		14 mo.	Yes	6 mo.	Empyema, pneumonia, renal thrombosis, uremia
Mrs. N. S.	34	Rt. pn'ectomy		Yes	10 yr.	Yes	15 mo.	Sudden death on 3rd day P.O. after plastic closure of bronchus
Miss V. D.	28	Rt. pn'ectomy	Yes		5 yr.	Yes	19 mo.	Sudden death on street
Miss S. B.	16	Rt. pn'ectomy		Yes	10 mo.	0	18 mo.	Contralateral tuberculosis

was an operative mortality of 11.1 per cent, representing five of the forty-five cases. The mortality rate for reasonable risks was 5.5 per cent, and for desperate risks, 33.3 per cent. There was only one late death in this group so that the total case mortality statistics vary little with the operative statistics.

Table VIII analyzes the postoperative deaths. As the table shows, seven of the ten postoperative deaths were classified preoperatively as desperate risks, only three as reasonable risks. Analysis of the cause of death in the three reasonable risk cases is quite interesting. One patient died of diabetic coma on the fourth day; the second died of a contralateral tuberculous pneumonia on the fifth day; and the third died of embolism on the fifteenth day. In only one of these reasonable risk cases did the patient die as a result of the tuberculous infection itself. The truly serious condition of the desperate risk patients can be gleaned from an analysis of Chart I. Five of them were complicated by the presence of tuberculous bronchitis; two of them had been ill for more than ten years; and two of them were over 50 years of age. In Case 7 a 25-year-old woman had very acute, progressive tuberculosis at the time resection was performed. The history indicated that disease had been present for only five months and the entire left lung had been destroyed. Her poor general condition and toxicity rendered her as a very desperate surgical risk.

Table IX analyzes the causes of the five late deaths. As this table shows, only two of these patients died of tuberculosis. One patient died of progressive suppurative disease and uremia six months after resection. In the case of Mrs. N. S., death occurred on the third day following a plastic closure of the bronchus. The patient had a smooth postoperative course until she suddenly became cyanotic, and within a few minutes was dead. Miss V. D. had completed six months' sanatorium treatment and was discharged with consent. She died suddenly while shopping. The cause of death was never determined. Her

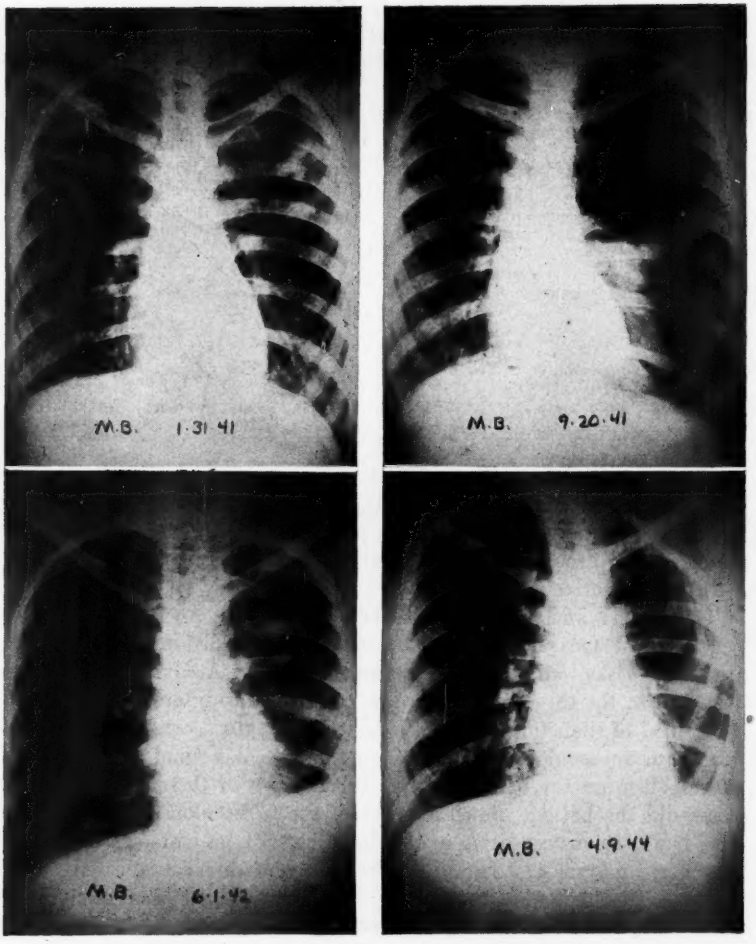

Fig 1*A*.—Miss M. B., aged 28 years. (Case 27 in Chart I.) Patient had been under treatment for 2½ years. Left pneumothorax had been continued for two years without closure of cavity or conversion of sputum. Left upper lobectomy was performed June 29, 1942. The postoperative period was uneventful. Sputum has been negative since operation. She is asymptomatic and well and has returned to full-time duty as a nurse. Resection in this case was elected in preference to thoracoplasty.

Upper left, Roentgenogram, Jan. 31, 1941, when diagnosis was made. This shows a scattered mixed type of infiltration in the left upper lobe with a small cavity at the level of the second rib. The right lung is clear.

Upper right, Roentgenogram, Sept. 20, 1941, three months after induction of left pneumothorax. In spite of adequate collapse, the cavity was still open.

Lower left, Roentgenogram, June 1, 1942, just prior to resection. Cavity is still open and sputum still positive.

Lower right, Roentgenogram, April 9, 1944, twenty-three months following resection. The contralateral lung has remained clear. Few nodules in apex of left lower lobe have not changed in appearance. The modified thoracoplasty was performed merely to prevent overstretching of the left lower lobe.

Comment, This is not the type of thoracoplasty which is now routinely advocated following lobectomy. Refer to Fig. 2*A* for an illustration of the type of thoracoplasty now performed in which the first rib is left intact, and the transverse processes are not resected.

sputum had been consistently negative and she had been asymptomatic and well since the time of resection nineteen months before.

The analysis of these four tables (Tables VI through IX) dealing with mortality statistics permits the following conclusions:

1. The operative mortality in reasonable risk cases has been reduced to a respectably low level, in the neighborhood of 5 per cent.

2. The operative mortality in desperate risk cases has been reduced to 33.3 per cent. Considering the imminently fatal issue facing these patients, results justify any figure.

3. Approximately one-half of the postoperative deaths has been due to the tuberculous infection. The other one-half of the postoperative deaths has occurred as a result of complications of the surgical procedure or associated disease.

4. Of the postoperative deaths, 70 per cent occurred in desperate risk patients.

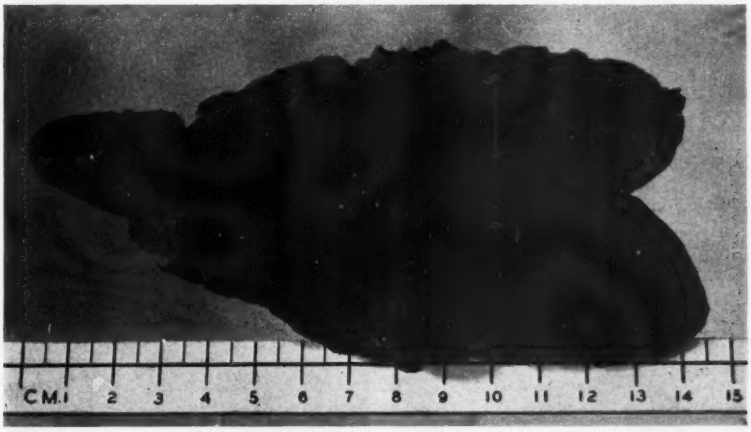

Fig. 1*B*.—Surgical specimen (left upper lobe) which shows the residual cavity in the left upper lobe. The scattered caseous nodules cannot be well seen in this photograph. Pathologic report described a small cavity 1.2 cm. in diameter, filled with inspissated gray mucopus. Scattered through the rest of the parenchyma were small to medium-sized, discrete to confluent, firm, gray foci identified as tuberculous.

CLINICAL STATUS OF PATIENTS AT THE PRESENT TIME

Of the entire sixty-one patients, fifteen have died. Of the remaining forty-six patients, thirty-four are clinically well. Of these thirty-four patients, twenty-six have returned to their homes and to normal activities; the other eight patients are either still in the sanatoriums or at home on modified bed rest under supervision. Five additional patients are well, but their sputa have remained positive. Two patients have progressive contralateral tuberculosis, and two have residual disease in remaining lobes on the side operated upon following lobectomy. One patient, who originally had a right lower lobectomy and subsequently developed ulceration of the bronchial stump, which spread to the right upper lobe, has recently had a right upper and

middle lobectomy. Her progress to date is satisfactory. One patient, operated upon in March, 1940, is a respiratory cripple. She has a residual empyema space and fistula. The remaining patient recently developed a bronchial fistula and mixed empyema nine months after pneumonectomy.

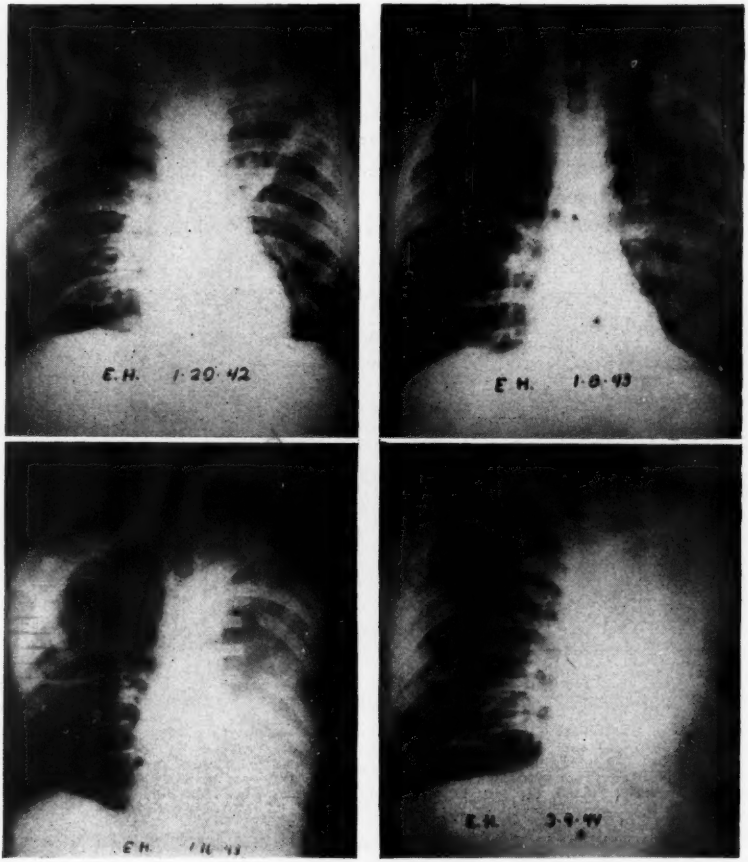

Fig. 2A.—Mr. E. H., aged 38 years. (Case 41 on Chart I.) Patient had been ill for thirteen months prior to resection. Left pneumothorax had been present for six months. The cavity in the left upper lobe had increased in size under pneumothorax. A left pneumonectomy was performed Jan. 12, 1943. This operation was elected in preference to an extensive thoracoplasty. Following operation, the patient developed contralateral spread which had entirely cleared within six weeks. The patient is asymptomatic and well. His sputum is negative including guinea pig inoculation. He has returned to work.

Upper left, Roentgenogram, Jan. 29, 1942, which shows exudative lesion in the left upper lobe with a small cavity at the level of the left second interspace. The contralateral lung is clear.

Upper right, Roentgenogram, Jan. 8, 1943, shows marked increase in the size of the cavity since induction of left pneumothorax in June, 1942.

Lower left, Postoperative portable roentgenogram of chest taken on fourth postoperative day shows contralateral spread.

Lower right, Roentgenogram, March 4, 1944. The contralateral spread has cleared. The routine type of postpneumonectomy thoracoplasty has been performed leaving the first rib and transverse processes intact. Thoracoplasty is performed in these cases to prevent marked mediastinal shift and the resultant compensatory emphysema of the contralateral lung.

In reference to the sputum in the forty-six living patients, only thirteen are known to have positive sputa on smear or concentrate. In the remaining thirty-three, as listed here, all patients are clinically well:

1. Nine patients show negative results on all tests including guinea pig inoculation of either the gastric or bronchoscopic specimen.

2. In one case negative results are found on all tests including culture of the sputum.

3. Four patients give negative results on all tests including concentrated examination of the gastric specimen.

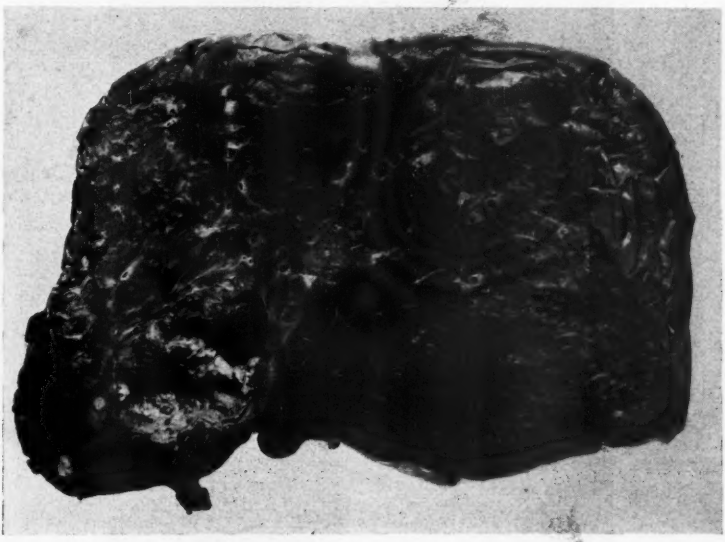

Fig. 2*B*.—Surgical specimen (left lung). There was a 5 by 5 by 3 cm. cavity in the left upper lobe. The adjacent portion of the lower lobe was atelectatic. There were scattered caseous nodules in both lobes. The posterior portion of the fissure line was obliterated and this area was involved by tuberculosis.

4. Eight patients have consistently negative direct smears. Seven of these eight patients are asymptomatic and well and have returned to their homes. One patient, who is still in bed, has a contralateral lesion, but is asymptomatic and clinically well.

5. Five patients have had no sputum examinations following resections. The reason for this lack of sputum examination is listed in the various institutions as "no cough or expectoration."

6. One case is negative on repeated concentrations.

7. Two patients give negative results on all tests except for guinea pig inoculation of the bronchoscopic specimen.

8. Two patients show negative results on all tests except for guinea pig inoculation of gastric content in one, and sputum specimen in the other.

9. One patient, who had a resection in 1934, is listed as having insufficient data for classification. However, she is clinically well nine years after resection, and this is strong evidence of a negative sputum.

DISCUSSION

In recent years the limitation as well as the usefulness of various types of collapse procedures has been more keenly appreciated. Their relative ineffectiveness in the control of many tuberculous lesions is now generally recognized. This is especially true of patients with endo-

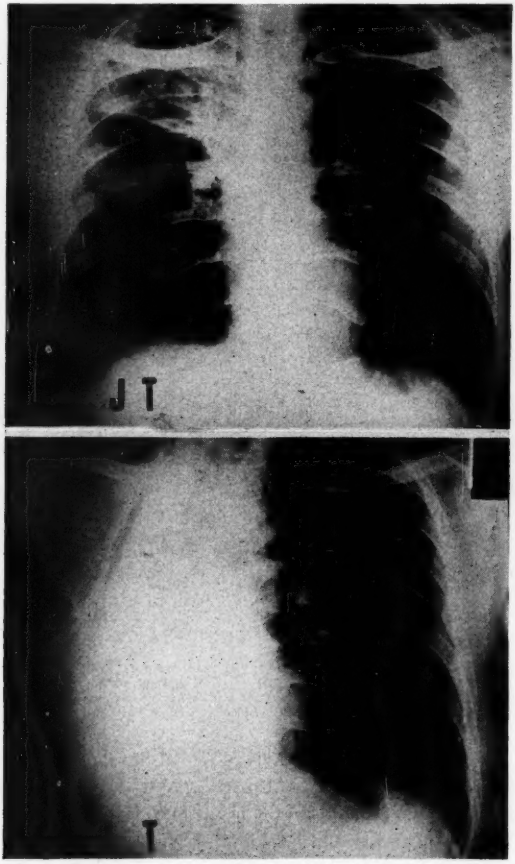

Fig. 34.—Mr. J. T., aged 34 years. (Case 39 in Chart I.) Duration of symptoms was seven weeks. The patient had moderately severe diabetes. His chest film had been negative two years before. Bronchoscopy revealed edema, redness, and partial occlusion of the right upper lobe orifice. Right pneumonectomy was performed Dec. 11, 1942. The postoperative course was uneventful. He remained well and sputum was consistently negative on seventy-two-hour concentrates until Sept. 11, 1943, at which time a routine bronchoscopic examination revealed ulceration in the bronchial stump. The secretion from the stump was positive on direct smear. The bronchus was treated with 30 per cent silver nitrate. The stump is completely healed at the present time, and the secretions aspirated directly from the stump are negative on all tests, including guinea pig inoculation.

Upper, Roentgenogram immediately preceding resection showing diffuse infiltration of the right upper lobe in which there is a 2 cm. cavity. There is another cavity in the lower lobe containing the rounded density seen in the x-ray. The left lung is clear.

Lower, Roentgenogram, April, 1943. The left lung has remained clear. A routine postpneumonectomy type of thoracoplasty has been performed.

bronchial tuberculosis, extensive basal lesions, tension cavities, and in exudative and caseous lesions in the teen-age group. The need for new procedures to be added to our armamentarium in the treatment of this disease is evident.

As the presented statistics show, pulmonary resection today offers the reasonable risk patient definite treatment with a good margin of safety. As the indications for its use widen, the safety will undoubtedly increase further. The present-day status of pulmonary resection has been developed in spite of the fact that the vast majority of patients who have been referred for it have been those with extensive or complicated forms of tuberculosis. More recent experience with truly elective cases has been very encouraging. Results in this type of resection have been almost uniformly good.

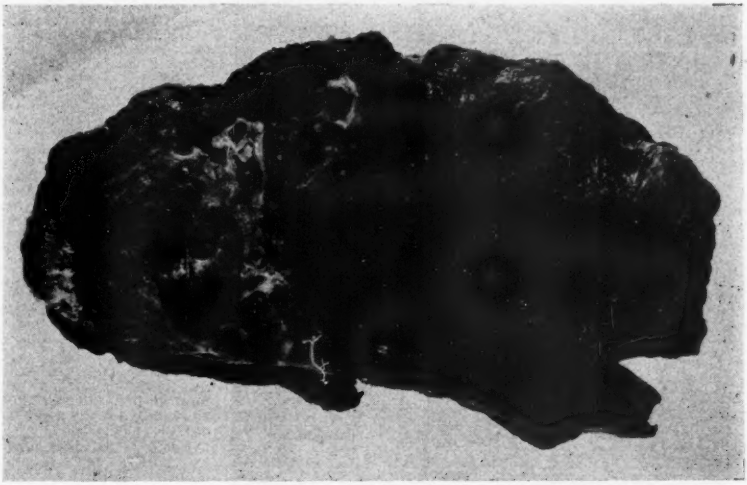

Fig. 3*B*.—Surgical specimen (right lung) which shows the large cavity in the right upper lobe. Unfortunately, the specimen has been cut on several plains so that the cavity in the lower lobe cannot be distinctly outlined. Several of the segmental bronchi were found to be positive on pathologic section.

Although it may be unwise to outline specific indications for an operation which has evoked so much controversy, our experiences prompt us to consider resection as the treatment of choice for the following types of disease:

1. In preference to thoracoplasty in cases with active parenchymal disease complicated by bronchial stenosis
2. Extensive basal tuberculosis with or without associated bronchiectasis
3. Unilobar disease that has failed to respond to pneumothorax with apparently adequate collapse
4. Unilateral disease that has failed to respond to an adequate thoracoplasty

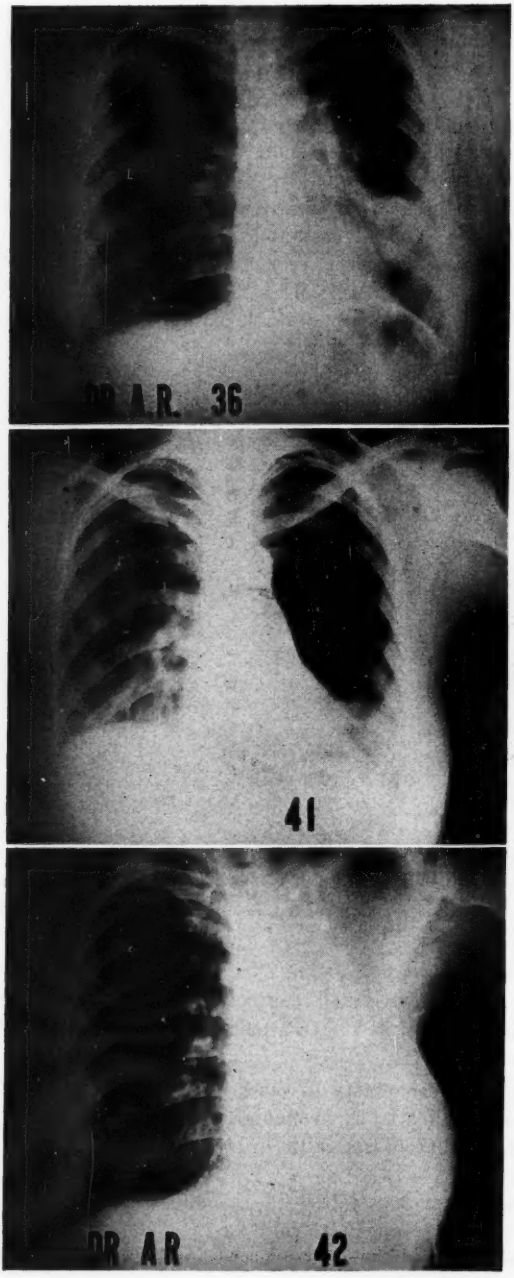

Fig. 4A.—Dr. A. R., aged 32 years. (Case 21 in Chart I.) Patient had been ill for six years and had had left pneumothorax during this entire time. Bronchscopy revealed an ulcero-stenotic lesion involving the left main bronchus. The entire left lung had become opaque and was not expandable. Left pneumonectomy was performed Jan. 28, 1942. Patient had an uneventful postoperative course and has been clinically well since that time. Sputum has been consistently negative on smear.

Upper, Roentgenogram in 1936, prior to the induction of pneumothorax, showing a basal lesion. The contralateral lung is clear.

Center, Roentgenogram in 1941, just a few months prior to resection, showing the collapsed, opaque left lung.

Lower, Roentgenogram in April, 1942, thirteen months following left pneumonectomy. A postpneumonectomy thoracoplasty has been performed.

5. In preference to cavernostomy in the treatment of tension cavities in unilobar or extensive unilateral disease
6. Extensive unilobar disease with dense opacities and little evidence of fibrosis and retraction
7. Progressive unilobar or unilateral tuberculosis in the teen-age group
8. Tuberculoma

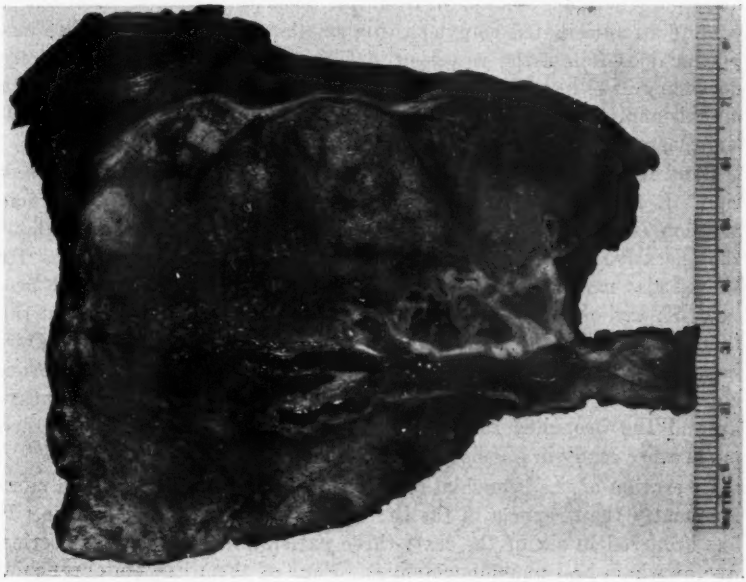

Fig. 4*B*.—Surgical specimen (left lung) shows the marked thickening of the pleura. The stenotic lesion in the main bronchus can be seen very well. The entire lung was quite fibrotic and contained numerous caseous nodules throughout. The bronchial system was markedly involved by a tuberculous bronchitis.

Thoracoplasty is not deliberately performed prior to resection, as advocated by Dolley and Jones.[3, 4] In fact, we consider thoracoplasty to be contraindicated for the following reasons.

1. The danger and complications of thoracoplasty are quite definite, especially in the group of patients for whom resection is proposed. Preliminary thoracoplasty subjects the patient to hazards of multiple chest operations with the disease lung in situ.

2. The presence of thoracoplasty complicates exposure; it prolongs the procedure and makes it more shocking. The interval between the beginning of the operation and the preliminary ligation of the bronchus is prolonged. The ultimate exposure is usually inferior to that secured when thoracoplasty is not present.

3. The mobilization of the lung is more difficult in the patient who has had thoracoplasty.

4. The reduction in the capacity of the pleural cavity following thoracoplasty is often a disadvantage in the postoperative care of the

resection patient. Because of this limited, fixed space, the pressure changes incident to the collection of fluid in the pleural cavity occur much more rapidly than they do in the larger space of the normal hemithorax.

5. Although the incidence of empyema is extremely low following resection, fear of this complication is not a bona fide reason for carrying out a preliminary thoracoplasty. It has been argued that the hemithoracic space should be reduced prior to resection in order to confine an anticipated empyema to a smaller space. In fact, if an empyema does follow the resection, drainage and space obliteration are necessary in either event. A preliminary thoracoplasty demands then a revisional type of operation which is more complicated than a routine postpneumonectomy thoracoplasty.

Contralateral spread is still the greatest hazard of pulmonary resection. It remains a challenge to both the anesthetist and the thoracic surgeon. The anesthetist should apply adequate suction throughout the operative procedure to remove all tracheobronchial secretions. He should also maintain the patient in an even plane of anesthesia to prevent marked changes in the depth of respiration and thus prevent the tendency toward the aspiration of secretions into the good lung. During the past nine months, an attempt has been made to prevent bronchial flooding by making it a point to place a temporary ligature around the bronchus early in the dissection. This is accomplished much more easily in pneumonectomy than in lobectomy.

Ulceration of the bronchial stump is a complication that occurs more frequently than reports in the literature would lead us to believe. It has occurred in six of the sixty-three patients in this resection series, five of whom had pneumonectomies. Four of them had endobronchial tuberculosis prior to resection and in one of these cases the resection was performed through an active area of ulceration in the bronchus. The diagnosis of this complication can be made only by routine bronchoscopic examination following operation. The examination of the sputum in these cases is misleading. On repeated concentrated examination of the sputum, all except one were consistently negative. Two were positive on guinea pig inoculation of the sputum and a third was positive on gastric. The bronchoscopically aspirated specimens on all of them were positive by smear methods. Bronchoscopic examination is indicated about six weeks following resection to discover any early ulceration. If this examination is negative, it is advisable that another be performed in about six months. Treatment with local application of 30 per cent silver nitrate has given gratifying results in these cases. Four of the six cases have been controlled by this method.

The optimum time for resection is variable. However, we believe that pulmonary resection can be performed safely in the presence of an extending active lesion. Tuberculous empyema, bronchial fistula, and implantation of infection in the incision have not been encountered more frequently when operation has been performed in the pres-

ence of active disease. It is not necessary for the patient to establish a so-called immunologic equilibrium by indefinite delay. Contrary to this conception, we feel that many patients have been robbed of their only chance to get well by unnecessary delay, in the hope that a progressing lesion would quiet down.

The condition of the contralateral lung is always a matter of great importance when pulmonary resection is being considered. When pneumonectomy is anticipated, criteria with respect to the contralateral lesion must be more rigid than when lobectomy is to be performed. However, we do not feel that the contralateral lung must be absolutely clear. To be a contraindication to resection, the contralateral lesion must be either uncontrolled or uncontrollable. Here again the decision will depend on whether pneumonectomy or lobectomy is anticipated. Pneumothorax is permissible on the contralateral side in lobectomy cases, but not following pneumonectomy. Bed rest alone must be relied upon in the case of pneumonectomy to control the contralateral lesion if one is present. A great many of the patients in this series had at some time during their illness a contralateral lesion. Many of these were fairly extensive. The vast majority of cases handled the contralateral lesion without difficulty, as evidenced by the fact that only two of the living patients have progressive contralateral disease.

The extent of resection cannot always be determined definitely prior to exploration. At times, considerable disease will be found in a lobe where it was not previously suspected by x-ray studies. It is very difficult to determine by palpation whether the lesions are active or inactive and one must rely more upon the extent of the pathologic progress in determining how much lung tissue is to be resected. It must be remembered that the operation is being performed, not only to remove the most evident offending lesion, but to remove all foci which are disseminating tubercle bacilli. The complete conversion of sputum is a prerequisite of success in any curative form of treatment of pulmonary tuberculosis. Our experience to date has shown that the resection of too little, and not too much, lung tissue may be responsible for an unsatisfactory result. On purely technical grounds, the resection can be limited to a lobe in almost all cases if the disease is so limited. However, on two occasions we have found lobectomy to be impossible because the tuberculous infection extended directly across the fissure line to involve the adjacent portion of another lobe. In one case, the cavity actually extended across the fissure line and involved not only the posterior portion of the upper lobe, but the superior division of the lower lobe. In such cases, a decision must be made between pneumonectomy and lobectomy plus segmental resection of the involved portion of the remaining lobe.

SUMMARY AND CONCLUSIONS

1. Resection of the tuberculous lung does not present unusual technical difficulties. In fact, the individual ligation of the hilar structures

can be accomplished with greater ease than in cases of pulmonary suppuration or malignancy.

2. The modern operative technique, with meticulous closure of the bronchus with silk sutures, and the reinforcing pleural flap, has almost eliminated bronchial fistula and empyema as complications.

3. Contralateral spread and ulceration of the bronchial stump, as real hazards of resection, present a challenge to the thoracic surgeon.

4. Active tuberculosis in the lung to be resected, even if it is rapidly spreading, is not a contraindication to resection. In fact, delay often robs these patients of their only chance to get well.

5. Tuberculous bronchitis, either active or inactive, is not within itself a contraindication to resection even if it has to be traversed during the procedure. On the contrary, this complication is often an indication for resection.

6. A contralateral lesion is not in itself a contraindication to resection unless it is uncontrolled or uncontrollable.

7. With the modern operative technique, the operative mortality in reasonable risk cases has been 5.5 per cent, and in desperate risk cases, 33.3 per cent.

8. At the present time, the indications for pulmonary resection in pulmonary tuberculosis are extending rapidly. We feel that it should be the preferred treatment in certain complicated forms of tuberculosis and for disease in which collapse has failed or is known to be relatively ineffective.

9. In the therapy of any case of pulmonary tuberculosis, pulmonary resection should be considered as a possible method of treatment. It should ideally be applied before extension of disease beyond its original site. It should ideally be applied before complications of the original disease develop. It should ideally be applied before the disease causes general debility and the fatal issue is obvious. In other words, spreads, complications, and failure of other methods should be anticipated in advance. The definitive treatment by resection should be considered at a time when the principal disease-bearing tissue can be ablated and the maximum amount of healthy lung conserved.

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